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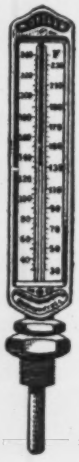

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EDITORIAL

Know Thy Dead Times!

ECHOES of that automatic-control "mystery" continue to come in—mostly as questions not for publication. Some new readers hadn't learned that close control requires a fast primary element. So here goes another sermonette on the thermometric lag.

Plunge your finger momentarily in boiling water; you'll say "ouch!" Now quickly pass your finger through a Bunsen flame: you'll hardly feel its heat. The same primary element (your finger) is faster in one medium than in another. This is true of ANY primary element. Moreover, the response curve depends on the circulation, especially in gases. A home thermostat that always acts too late in a stagnant-air location becomes alert when relocated in good circulation.

The lag coefficient is not an unchangeable measuring property. A characteristic which IS the same in any medium at any circulation is THERMAL MASS. Thermal mass is important because it imposes an irreducible limit to the speed of response. Your fastest mercury-in-steel recorder will draw a smooth line at 50°C. or 122°F. if you plunge the bulb alternately in ice-water and boiling water . . . until you tire and slow down, when the record will change from a smooth line to something like this:

which is far from a 2" high square wave!

The fastest elements I know of are the fine-wire resistance thermometers which physicists have successfully used as speech pick-ups (lag coefficient in air obviously less than a millisecond). Commercial resistance-thermometer wire can be made into a primary element with a 1-millisecond lag in liquid. A thermocouple junction hammered or rolled to microns thickness will be equally fast.

We can't use these elements bare in our control systems. We must support them and protect them—and we get a primary-element *assembly* with a relatively large THERMAL INERTIA. Thermal inertia depends not only on thermal mass but on SHAPE, nature of outer surface (even *color!*) and many other factors. Its effect on the response curve is so unpredictable that you have to run your own response-curve tests for every new combination. Take a bare wire which gives an oscillograph curve attaining 63% of final reading in a millisecond; enclose it in a kiln type protecting tube and the assembly may take more than a quarter-hour for 63% of final reading . . . a millionfold increase! Or it may be "only" a thousandfold increase: you wouldn't know unless you ran a test.

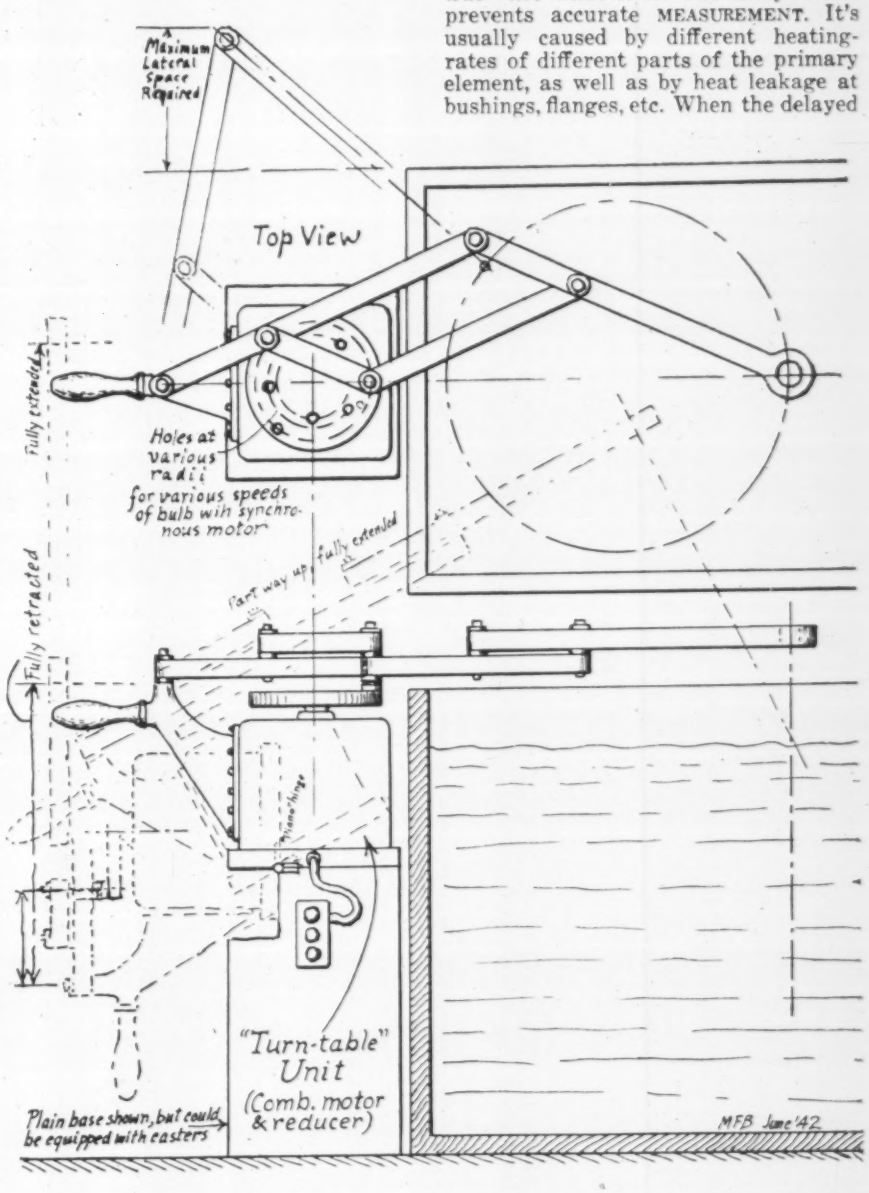
To determine the *complete* response curves (including delayed starts and delayed ends) of your own primary elements under your own conditions isn't impossible. Sometimes it's easy. The essentials are fairly obvious. One is a fast recorder, preferably an oscillograph. Another is a means for suddenly transferring the bulb or couple from room temperature to the medium under study. Another essential is *known circulation.* No need of a hydraulic-laboratory setup: plunge your bulb or couple into the *still*-medium tank suddenly and make circles by hand inside a fixed hoop (constant-diameter) while humming a marching song to maintain a speed of 130 r.p.m. Or save your arm muscles and build a set-up like the one sketched here (which can be shipped to another plant when you're through with it).

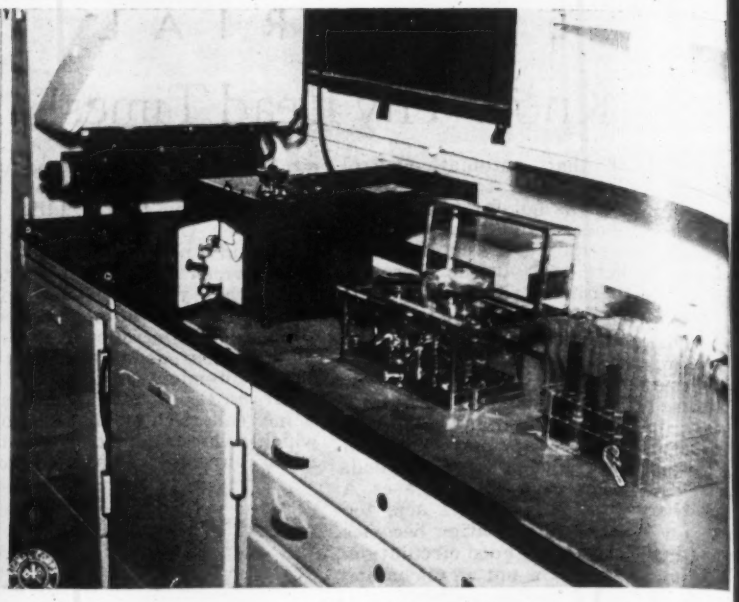
Dead times mean dead zones. In some applications controller dead time, rather than process dead time, is the unsuspected offender. Unsuspected because it occurs in the form of the delayed start. Some readers think that a bulb or couple which exhibits the delayed-start effect when purposely subjected to a large sudden change (say 100°C. to give an easily-read record) will have a negligible delayed start when subjected to a smaller change. Seldom is this true. The delayed start may be longer!

A primary-element dead time may remain unsuspected when it is the interval between the beginning of a *gradual* change in the controlled temperature and the instant when the signal crosses the upper or lower limit of the controller mechanism's dead zone. At *that* instant, the actual process temperature deviation may be twice, or twenty times, the width of the mechanism's dead zone, and of course the deviation continues to increase after that instant because of process dead time.

Controller dead *time* may remain unsuspected because although it is possible to build a control *mechanism* without a dead ZONE this is not true of any controller as a whole. A controller comprising an "ideal" mechanism and a too-heavily-protected thermocouple may remain inactive while the furnace temperature oscillates 20° above and below the control point.

The delayed start is the enemy of close control: it means that you're always controlling what the temperature *was*—not what it *is*. The delayed END prevents accurate MEASUREMENT. It's usually caused by different heating-rates of different parts of the primary element, as well as by heat leakage at bushings, flanges, etc. When the delayed end is bad, it's ENDLESS: the signal from the primary element (millivoltage, pressure, etc.) *never* gets to represent the "true" temperature you want to measure; instead, it represents a temperature somewhere between this true temperature and the temperature of the wall through which you've installed your primary element.—M. F. BEHAR.


Maximum Lateral Space Required
Top View
Fully extended
Holes at various radii for various speeds of bulb with synchronous motor
Fully retracted
part way up
fully extended
"Turn-table" Unit
(Comb. motor & reducer)
Plain base shown, but could be equipped with casters
MFB June '42



(LEFT) In the Quartermaster Corps Mobile Chemical & Bacteriological Laboratory, Capt. Hatton B. Rogers, food technologist, places plate containing bacteriological specimen from processed food in automatically-controlled incubator to determine bacteriological count. These plates are kept in incubator 24 to 48 hours at temperatures from 98°F. Below is freezing compartment; at right is a vacuum oven which determines moisture content in dehydrated foods. (RIGHT) Work bench showing vacuum drying oven, Beckmann pH meter to test acidity of certain processed foods, balance, etc.

Mobile Food-testing Laboratory Prevents Contaminated Food From Reaching Soldiers

By Colonel ROHLAND H. ISKER, Director, Subsistence Research Laboratory, Chicago Quartermaster Depot; Chief, Subsistence Section, Research & Development Branch, Military Planning Div., OQMG

A MOBILE food testing laboratory, constructed earlier this year by the Quartermaster Corps to aid food processors in development of methods for eliminating spoilage from canned goods under storage conditions, has completed its initial circuit. Results were that potential spoilage was eliminated from nearly a half million dozen cans of peas, some of them destined for shipment to our soldiers overseas, and its presence detected in more than a half million others.

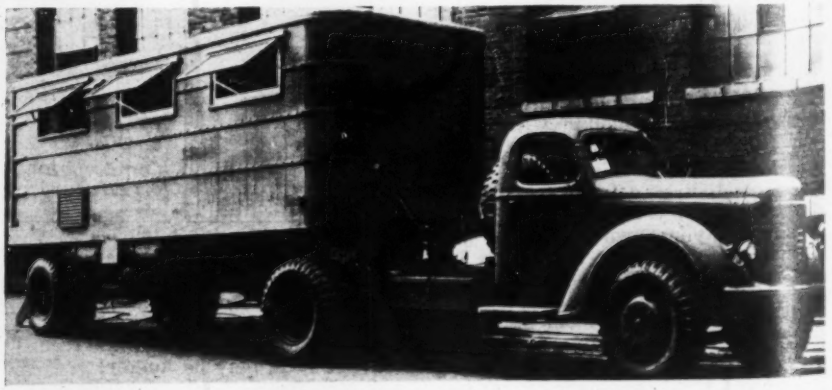
"Flat sour" spoilage in canned goods is caused by a thermophile (heat-loving) microbe which is active at high temperatures such as those under a tropical sun. According to the Office of The Quartermaster General, canned goods which may contain inactive thermophiles are harmless unless subjected to temperatures well over 100°F.

Although it is the practice of Quartermaster units operating with combat troops to get subsistence and other supplies under cover as soon as possible, conditions in tropical campaigns have been such at times that supplies of canned goods have had to be stored in the open, until sheds, thatched with Nepa palm or other local materials could be provided to protect them from the sun's direct rays. Operation of the traveling laboratory assures that a minimum of the food shipped into such areas carries with it the "flat sour" thermophile.

Designed after extensive tests in the Mojave Desert had shown that food cannot be kept at temperatures higher than 130°F. and that even at 100° in the hot sun the "flat sour" thermophile will go to work, the mobile laboratory is set up in a large truck-trailer of the same size and type as the Quartermaster Corps mobile shoe repair and clothing repair units now being used in overseas theatres. It is insulated and air-conditioned for better control of atmospheric conditions which might prevail during work in the field, and is staffed by experienced officers and food technicians from the Quartermaster Corps Subsistence Research Laboratory at Chicago. At this writing, it is being used in similar studies in other food processing industries to prevent the shipment to troops of food which may be of no value to them upon delivery or, if eaten, might put the men out of action for several days.

Presence of the "bug" itself, in its inactive state, is harmless to humans. Only the effect of its activity upon the contents of the cans in which it may become active is harmful. The term "flat sour" is applied to the form of contamination caused by this particular thermophile because cans so contaminated do not bulge at the ends, as do

Continued on page 712



The Quartermaster Corps Mobile Chemical & Bacteriological Laboratory. It is constructed on a ten-ton Army type trailer-truck chassis, of the same size as those used for Army shoe and clothing repair units overseas. It is insulated and air-conditioned, and equipped with the finest food-testing devices.

Adjusting Fan-speed Controllers for Best Results in Boiler-plant Control Systems

By DON BURNS, Control Division Engineer, The Hays Corp., Michigan City, Ind.

I. Introduction

In recent years, manufacturers of steam-generating equipment and manufacturers of automatic-control equipment for steam generators have done much to complement the efforts of each other, the first to make the steam-generating equipment more controllable and the latter to make finer control equipment.

Most steam generators being installed at present have either forced- or induced-draft fans, or both — many equipped with dampers and many driven by steam turbines or constant-speed motors through electric or hydraulic coupling drives for control. It has been found economical to use a variable-speed drive rather than dampers with a constant speed drive, if such drive is controllable through a suitable range of capacities.

The characteristics of all of these drives are similar. They accelerate rapidly and decelerate slowly at low speeds; and they do just the opposite near top speed. They differ primarily in their designs and, consequently, the overall accelerations and decelerations of different types or makes are different, as are also their inertia capacities, but they all approach their set speeds asymptotically and they closely follow an exponential curve of acceleration.

Moreover (and this is fortunate in the search for fan equipment to do a better job more economically) the newer fan drives are quite uniform in their characteristics, so that "proportional bands" may be estimated with reasonable facility and accuracy. "Floating rates" also may be estimated but it has been found that changing "floating rates" slightly may cause a marked difference in control, particularly if both forced- and induced-draft fans have variable-speed drives.

II. Steam Turbines

(A) Steam turbine drives may be controlled either (1) through the governor on the turbine or (2) by a throttle valve in the steam line ahead of the turbine, allowing the governor to be a maximum-speed governor only.

(B) Hydraulic couplings are ordinarily used with constant-speed induction or synchronous motors to obtain variable fan speeds. For control purposes they may be classified as (1) the scoop type, on which a lever is moved to govern the load carried through the coupling, and (2) the pump type, in which oil is pumped in or out of the coupling to change its load-carrying capacity. While the characteristics of these two types are similar, the method of control must differ, since on the pump type coupling there is no "reference position" such as the lever position on the scoop type or the valve position on a steam turbine.

(C) The electric coupling's action is similar to that of the hydraulic coupling except that a rheostat arm is moved and serves as the positional reference.

(D) Other drives may consist of variable-speed d-c. or a-c. motors and some mechanical drives, but these are seldom used.

III. Controller and Data

In order to bring out clearly the basis upon which the "proportional bands" and "floating rates" are set, a diagram of the controller is shown (see Fig. 1). This consists of a differential diaphragm assembly, actuating contacts

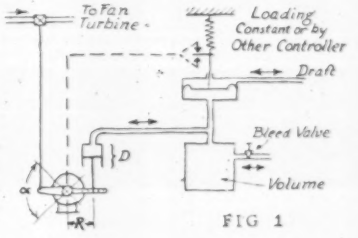


FIG 1

and loading means. The pressure or draft is connected to one diaphragm chamber and the "proportional" and "floating" mechanism of the controller is connected to the other chamber. The "proportional band" chamber, "floating rate" bleed valve, connecting tubing, piston and cylinder at the drive unit, and the valve in the steam line of the turbine, together with its linkage, complete the controller.

It will be seen that the "proportional band" chamber is normally at atmospheric pressure and that the "proportional band" of the controller may be calculated closely by the relation of piston displacement to chamber volume since the pressure does not vary appreciably from atmospheric.

$$P = bD/V$$

P—"Proportional band"—inches water
b—Atmospheric pressure — inches water
V—Volume of "proportional band" chamber—cubic inches
D—Piston displacement for full travel of power unit—cubic inches

To obtain a rough adjustment of "proportional band" for any given fan and variable-speed drive, it has been found that the chamber volumes may be arranged to give from 350% to 700% of the control-point pressure. For example, a controller measuring forced-draft duct pressure at 2″ water setting point, and controlling the speed of a turbine-driven forced draft fan by means of a valve in the steam line to the turbine, would have a "proportional band" chamber of about 260 in.^{3} and a piston displacement of 4.5 to 9.3 in.^{3}.

It will be noted that, for a given chamber, some adjustment in "proportional band" is available by adjusting the piston-rod crank radius R and power unit angular travel α. (In all three figures, the minima are 90° angular travel and 1¼″ crank radius and the maxima are 135° angular travel and 2″ crank radius.)

These "proportional bands" are somewhat beyond the "critical proportional band" but it has been found that if the valve does not have a linear relationship of flow to position, or if the linkage between the drive unit and valve is not set to compensate for valve characteristic, the system will hunt at one speed and remain stable at another. In any case, the wider "proportional band" will tend to stabilize the controller. It will also be remembered that seldom, if ever, is the controller called upon to use its full "band" since its boiler cannot (and is never required to) keep up with the agility of the fan.

The horsepower, diameter and weight of the fan and turbine parts and speed of the fan do not necessitate too marked a difference in "proportional bands," probably because today most fans are quite accurately figured and seldom is a case encountered where the fan is much too large for the job or where a steam valve of proper capacity cannot be obtained.

Although the above discussion has reference to turbine-driven fans, the controllers for fans driven by hydraulic and electric couplings would have about the same "proportional bands" and will come within the adjustment shown in the following table:

Setting point, inches water:		0-1	1-2	2-3	3-4	4-5
Chamber capacity (incl. tubing) cubic inches		489	258	181	142	104
Piston displacement cubic inches		4.5 to 9.3				
"Proportional band" in. water	Min.	3.6	6.9	10.0	12.6	17.2
	Max.	7.6	14.5	20.7	26.4	36.1
% setting point "prop. band"	Min.	360	345	333	315	344
	Max.	760	725	690	660	722

The case of the pump type hydraulic coupling will be discussed later since its control involves only a change in method, not in constants.

The range of adjustment of "proportional band" having been determined by calculation and made a characteristic of the controller at the factory, it

*Presented at the Symposium on Automatic Controller Adjustments, Industrial Instruments and Regulators Division, Semi-annual Meeting of American Society of Mechanical Engineers, Pittsburgh, Penna., June 20, 1944.

is unnecessary for the user to worry about this not-too-well understood phase of the controller. He is called upon only to adjust the "floating rate" bleed valve and the crank radius, which becomes a relatively simple operation. (The angular travel is set accordingly to the installation drawing.) He is told to close the bleed valve, then open it about one turn and note the operation of the fan, in increments of a half-turn, keep opening the valve and noting performance until hunting occurs, and then close the valve one turn and lock it.

In general, the valve will finally be from two to six turns open, depending largely upon the control-point pressure and the performance of the fan, requiring from thirty seconds to three minutes for the chamber pressure to bleed to atmospheric pressure on a 20% speed change.

IV. "Leading" and "Following" Fans

A boiler's fan equipment sometimes consists of a variable-speed forced-draft fan for suppying combustion air and a variable-speed induced-draft fan for removing products of combustion.

The control system may, for example, be set up so that the forced-draft fan speed is controlled from fuel/air ratio and, in order to remove the products of combustion, a constant furnace draft is desirable, which means that the induced-draft fan must speed up or slow down with the forced-draft fan. Thus, we can say that the induced-draft fan is the "following" fan since it "follows" the forced-draft fan. Then, the forced draft fan is the "leading" fan.

It will be seen that in order to hold furnace draft constant, the acceleration of the forced-draft or "leading" fan must not exceed that of the induced-draft or "following" fan.* Likewise, it will be found that both fans will affect air flow more or less, according to factors in which we are not at present interested. Thus, we have two controllers controlling, to some degree, one air flow; and unless some care is taken in adjusting the "proportional bands" and "floating rates" of the two, a disagreeable if not violent hunting will occur as they get out of phase.

*EDITOR'S NOTE.—The word "following" as used by the author does NOT imply lagging behind the "leading" fan. The idea is that both fans should accelerate and decelerate simultaneously, as if linked to each other by a mechanical gear train which is adjustable for ratio but is free from backlash and inertial effects.—MFB

Here again, then, "precalibrating" the "proportional bands" of the controllers is of value. The controller of the leading fan is so arranged as to have a noticeably wider "proportional band" (usually about double) because of the necessity for holding down its acceleration; and because if one of the two fan controllers is stable, it will help the other to be stable.

This expedient is not always satisfactory, however, since if the fuel changes suddenly by reason of a sudden load swing, and if the fuel is gas or oil (one in which no appreciable lag occurs) an undesirable change in fuel/air ratio may occur until the fans have come to balance at the new air-flow rate.

It therefore is desirable to have the "leading" fan change its speed as rapidly as possible and simultaneously signal the "following" fan controller in what direction and how much its change was, even before it (the "leading" fan) has reached its new speed.

To accomplish this end, the drive unit on the "leading" fan automatic-control means is fitted with an extra piston and cylinder which is connected with the "proportional band" chamber on the

Continued on page 708

Empirically-determined Adjustments for Proper Control of Oil Outlet Temperature of Double-pipe Chillers*

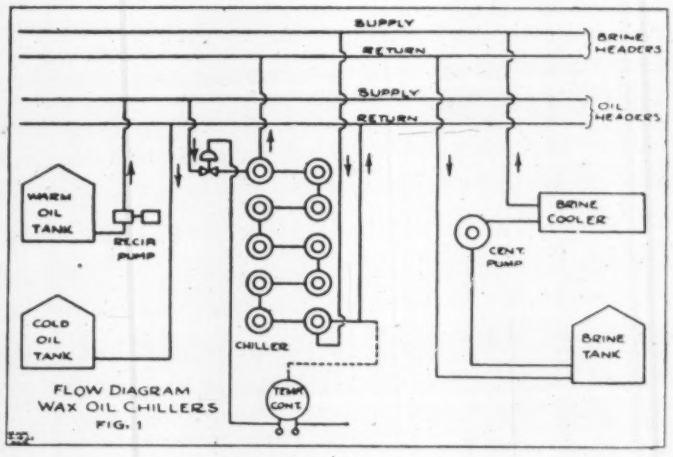
By MARTIN H. WHITE, Chief Instrument Engineer, Atlantic Refining Co., Philadelphia, Pa.

ABOUT thirty years ago a battery of 23 Carbondale double-pipe chillers as installed in the Paraffine Division of The Atlantic Refining Company's Philadelphia Refinery. The purpose of this installation was to chill the so-called "wax oil," preparatory to dewaxing in the presses.

By referring to Fig. 1 the oil flow may be traced from the warm oil tank to the reciprocating pump which raises the pressure to about 600 lbs./in.^{2} and discharges into the supply header which feeds the 23 chillers connected in parallel. From the header the oil flows through the control valve, then through the chiller to the return header and then to the cold oil tank.

Brine is circulated by a centrifugal pump from the brine tank through the brine cooler of the refrigeration machine to the supply header and then through the chiller, counter-current to the oil, and back to the tank by way of the return header. Normally there are several brine coolers operating in parallel on this brine system.

Before automatic control was applied to these chillers, a hand-operated needle valve, located where the control valve is now, was used to control the outlet temperature. This manual operation required the full time of an operator for the 23 chillers; and the oil outlet temperature of any individual machine was likely to vary 5°F. or more from the desired temperature. The saving feature of the operation was the fact that all the machines discharged into a common tank, so that the resulting temperature was usually fairly constant. The oil inlet temperature is about 70 to 75°F. and for most dewaxing the outlet temperature is held at 18 to 20°F.



FLOW DIAGRAM
WAX OIL CHILLERS
FIG. 1

When we begin to investigate the possibility of applying automatic control to this process, the greatest obstacle encountered was the process dead time, which was of the order of ten minutes. This was caused by the fact that the throughput rate on each machine is only about 15 g.p.m. The logical solution from the purely control viewpoint seemed to be to hold the oil flow constant and put the control valve in the brine line.

There was, however, one serious objection to this method. The operation of

*Presented at the Symposium on Automatic Controller Adjustments, Industrial Instruments and Regulators Division, Semi-annual Meeting of American Society of Mechanical Engineers, Pittsburgh, Penna., June 20, 1944.

his proce was such that the limiting factor on production was the refrigeration available. This made it necessary to adjust the oil throughput rate to the refrigeration, rather than to adjust the refrigeration to the throughput.

Therefore, in order to utilize all the available cooling capacity, it was decided to put the control valve in the oil line as shown in the flow diagram. Since there was considerable doubt in our minds as to whether this method would give the desired control of ±2°F., an experimental installation was made on one chilling machine. The results obtained proved so satisfactory that all 23 chillers were later equipped with the same controls.

It was obvious from the magnitude of the lag in the process that a fairly wide "proportional band" setting and a slow "reset rate" or "floating rate" would be required. Floating control was necessary because load changes occurred rather often in the form of changes in brine temperature and wax deposits building up on the oil side of the chiller pipes. Fortunately, those load changes usually take place slowly.

To obtain the data given here, one chiller was selected and a pressure recorder was connected to the air line from the controller to the control valve to show the controller action. This instrument was set for maximum width of "proportional band" which is about 84%, and had a "reset" or "floating time" of 64 minutes. Fig. 2 shows a typical record of the temperature (right) and controlled air pressure (left) with these controller settings.

The width of the "proportional band" was then reduced to 54% and the cycling record shown in Fig. 3 was obtained. This setting does not always produce this cycle, but it occurs frequently enough to indicate that the control sensitivity is too high for normal operation.

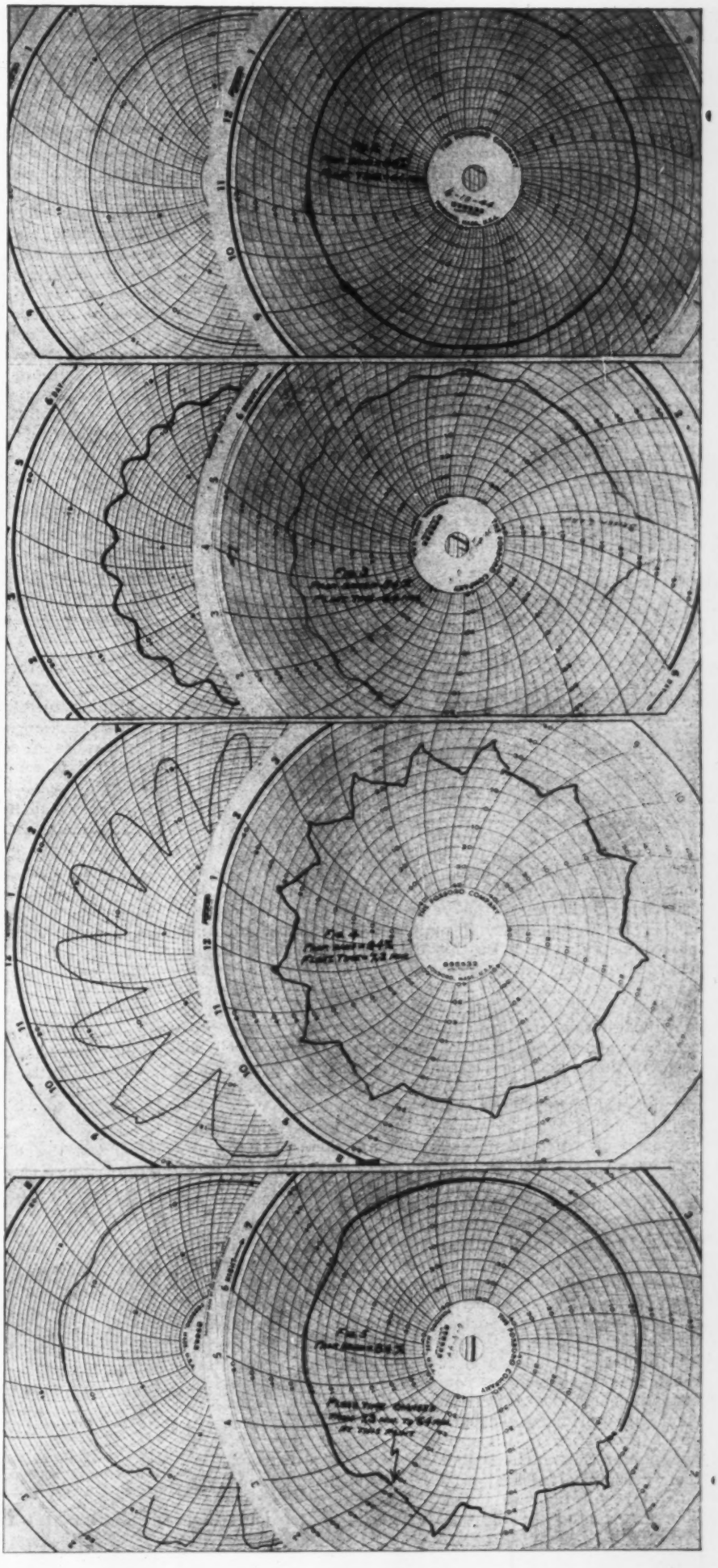
The "proportional band" setting was then changed back to 84% and the "floating time" was shortened from 64 minutes to 7.3 minutes. This is a large reduction, but it was as small as could be made conveniently with this particular type of controller. Fig. 4 shows how poor the control was with this setting.

Fig. 5 shows the actual transition from a floating time of 7.3 minutes to one of 64 minutes. When the change was made the cycle stopped and the temperature record straightened out again.

It is quite possible that a floating time adjustment of somewhat less than 64 minutes would give the most desirable operation but, with the slow load changes encountered normally in this process, the present settings are satisfactory.

Acknowledgement

The writer wishes to express his appreciation to Mr. W. W. Aldinger and Mr. W. S. Ferguson of the Paraffine Division for their assistance in obtaining the data used in this article.



ELECTRIC GAGING METHODS for Strain, Movement, Pressure and Vibration

By HOWARD C. ROBERTS, Research Staff, Association of American Railroads, Chicago, Ill.

V. GAGING METHODS BASED ON VARIATIONS OF RESISTANCE

(Continued)

§6. Electric Circuits

1. Series Circuits

The most elementary form of electric circuit used with resistance-type gaging elements is the series circuit, in which the gaging element is placed in series with a source of electric energy and an instrument to indicate (or record) the current through the element or the potential drop across it. Its arrangement is similar to the series circuits described in connection with the variable-capacitance and variable-inductance elements (see Fig. 25 and Fig. 46). It is a less elegant method than that of the bridge or balanced circuits, but because of its simplicity is widely used.

The basic series circuit is shown in Fig. 79. Its components are these: a source of electric energy of constant value, the gaging element itself, and a current-measuring instrument. In the diagram, the gaging element is the variable-resistance element *R*, the current-measuring instrument is indicated by *G*, and the source of electric energy is the battery *E*. With this form of the circuit, the criterion of change is the value of the current flowing; it therefore is necessary to maintain the applied potential at a constant value. In this diagram the battery *E* is assumed to maintain its potential constant; in actual practice a lead storage battery, if kept well charged, will serve for most applications.

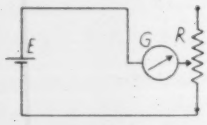


Fig. 79

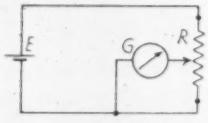


Fig. 80

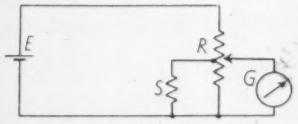


Fig 81

Although the circuit diagram indicates that direct current is employed, alternating current can equally well be used, if the indicating instrument is sensitive to a.c. But then it is necessary to insure that the impedance of the gaging element have no reactive component.

This basic series circuit is subject to certain disadvantages, of which the most serious are these: (1) the indicating instrument does not indicate zero current for zero movement, nor does it discriminate between different directions of movement; (2) the current required from the source of energy is variable and therefore difficult to regulate; and (3) the calibration of the device is not linear unless a tapered resistance element is employed. All three of these difficulties are resolved if the indicating instrument is so connected as to indicate the potential drop across the primary element (or a portion of it) instead of the current through it.

A diagram for such a circuit is shown in Fig. 80. Here the primary element is connected as a voltage divider instead of as a rheostat; the current through it is constant. Along this primary element the potential drop occurs in direct proportion to the resistance present; between any two points the potential existing will be proportional to their mechanical separation. An instrument indicating this potential will likewise indicate the distance between the points of contact. If the instrument is connected between one end of the element and a moving contact, it will indicate movement measured from the end of the element; if connected from the center of the element to a moving contact the instrument can indicate movements in either direction from the central position, and (if the instrument can also indicate polarity) can indicate both direction and extent of movement. It is assumed that the indicating instrument draws no current from the circuit; if the resistance of the instrument is many times higher than that of the gaging element this requirement is approximately satisfied.

Series circuits are best applied to moving-contact elements; when so applied they can be made to perform simple computations as well as to measure magnitudes. An especially useful modification of the circuit of Fig. 80 results if a shunt is applied to the moving-contact element or to a portion of it;[178] a typical arrangement is illustrated in Fig. 81.

The circuit of Fig. 81 differs from that of Fig. 80 only in that a shunt is applied to a portion of the slide-wire. Effectively, this shunt reduces the potential drop per unit length along this slide-wire by an amount equal to the shunt factor and, since the indicating instrument measures potential drop, the sensitivity along this shunted portion is reduced by the same factor. (The potential drop across the entire resistance element must be maintained at the proper value.) Such a shunt makes it possible to provide two different sensitivities along the same element; the calibration curve will have two intersecting straight-line portions. Alternatively, a shunt may be applied across the entire resistance element to control the sensitivity of the unit; when this is done the current flowing through the circuit must be maintained constant rather than maintaining the applied potential constant. Other applications are apparent.

These circuits, because of their simplicity, are deservedly popular. They require, however, accurately controlled exciting energy. For the circuit of Fig. 79 the voltage applied to the circuit must be maintained constant, while for the circuits of Fig. 80 and Fig. 81 the current flowing through the resistance element must be maintained constant (which is equivalent to constant potential applied across the resistance element). Of the several methods and devices employed to provide regulated current or potential, the most widely employed are these: for alternating current supply, constant-voltage transformers* or regulating resistors* may be used, or a regulating circuit employing a cold-cathode gaseous tube may be set up to provide small amounts of a.c. For d.c., electronically regulated power supplies and gaseous regulator tubes* are often employed. Regulating bridge circuits incorporating non-linear elements are used for either a.c. or d.c. A regulating bridge circuit[179] employ-

INVITATION

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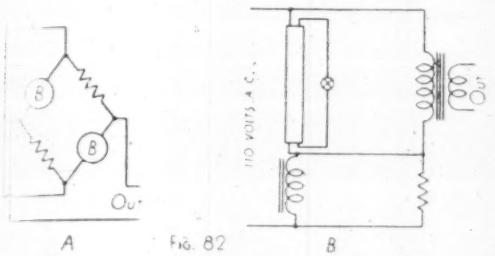
H. C. Roberts, Association of American Railroads, 59 East Van Buren Street, Chicago 5, Illinois.

*These are commercially-available units.

(178) P. G. Jones and H. F. Moore. An Investigation of the Effect of Rate of Strain on the Results of Tension Tests of Metals. *Proceedings American Society for Testing Materials*, Vol. 40, 1940, pages 610-624.

(179) E. J. Casselman. Automatic Voltage Regulator. *Electronics*, Vol. 14, October 1941, page 54.

...g incandescent lamps as non-linear elements is shown as Fig. 82A; a circuit employing a fluorescent lamp as a cold-cathode gaseous regulating tube[180] is shown as Fig. 82B. In Fig. 82A, if 190-ohm resistors and 75-watt tungsten-filament lamps are used the output voltage remains between 82 and 83 volts for input voltages ranging from 90 to 130 volts; in Fig. 82B if a 15-watt fluorescent bulb is employed



A Fig. 82 B

with the customary reactor, an output of about 10 watts of accurately regulated a.c. is available, with its voltage determined by the turns ratio of the transformer. Neither circuit is very efficient, but both are often employed because of their low first cost and simplicity.

If the use of the measuring circuit is not to be continuous, battery power can be satisfactorily used; it is only necessary to provide a voltmeter so that the applied potential can be adjusted as needed. A circuit embodying such facility for adjustment, long used as a torsion-type dynamometer,[181] is shown as Fig. 83. In this circuit, a single pointer-type instrument is employed, and a two-position switch is so connected as to make it possible at any time to check the

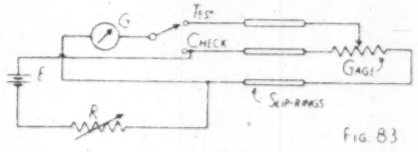


Fig. 83

potential applied. In this circuit, the indicating instrument serves simply to measure the potential across that portion of the slide-wire which is spanned by the contacts at any time. By operating the checking switch, the potential across the entire length of the slide-wire may be measured, and adjusted by means of the variable resistance *R*. The applied potential is adjusted until the indicating instrument shows full-scale deflection; then with the switch in the "Test" position the deflection of the instrument indicates the position of the sliding contact. In this circuit, the center position of the pointer represents zero movement, and the instrument scale is graduated to correspond to the slide-wire. The entire length of the slide-wire in the device is less than ¼", and the scale of the indicating instrument is 4" in length. Movements as small as 0.001" can be measured.

Because of their simplicity, robustness, and ease of application, these series circuits have been widely used in the measurement of movements in industrial (and other) machinery. As an accessory to a mechanical engine indicator, a slide-wire element has been employed to record electrically engine cylinder-pressures;[182] pressure gages have been constructed in which the deformation of a Bourdon tube or sylphon bellows causes a contact to move upon a resistance element.[183] For the measurement of small differences in pressure, variable-resistance elements consisting of resistance wires dipping in mercury have been used in series circuits; these may be linear elements[184] or they may be circular elements like that in Fig. 66A. The rigorous conditions experienced in industrial or military applications do not destroy the utility of these elements; they have measured the recoil of cannon[185] and the rudder motion of warships;[186] they have been applied to marine Diesel engines to measure vibration, expansive movements, and the motion of the valves;[187] in stationary installations they have performed similar services.[188] In the field of railway testing they have been installed on steam locomotives to indicate valve position for recording in a dynamometer car, and on cars to indicate the swing of the trucks and the motion of the draft-gear.[189] In the laboratory, they have been applied to measurements of strain in the testing of metals.[178]

The circuits just described, when employed with moving-contact elements, provide an indication of the motion of the contact in terms of the deflection of an indicating instrument, and therefore require calibration to afford a relation between movement and indicator deflection. Another sort of circuit, which can be employed only with moving-contact elements of the tapped-resistor form, requires no calibration if its output is recorded; it depends instead upon the mechanical spacing of the contacts, so that the calibration may be said to be built into the gaging element.

If a tapped element is installed with its output current recorded upon an oscillograph, the trace produced by movement of the contact will be a series of steps, each step being produced by the movement of the contact from one step to the next. The height of the steps (on the record) is irrelevant; it is their spacing which is important. A change in direction of the movement will produce a change in appearance of the record; they "step up" for motion in one direction, and "step down" when the motion is reversed. In Fig.

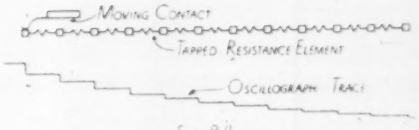


Fig. 84

84 is a sketch of such a tapped element, and below it a sketch indicating the appearance of the record produced. Such an element can be applied to measurements of extremely rapid motion and under rigorous conditions, as in the measurement of gun recoil.[185] It is of course possible to interpolate between steps, and it is possible to space the individual contacts as close as 1/20" without sacrificing strength or performance of the unit.

For measurement of movements of several inches, tapped elements of many steps are required, and it becomes tedious to count the many steps recorded by such an element. This difficulty is eliminated by a circuit first developed for recording the travel of the cross-heads of enclosed oil circuit-breakers.[190] In this arrangement a long array of contacts is connected electrically to a group of resistance elements in such a manner that the stairstep pattern is a repetitive one; the contacts are ⅛" apart and are connected in groups of four, with the starting contact set apart. The resulting pattern is a series of four steps up with an immediate return to the point of origin, and is repeated over each one-half inch interval. Quite close spacing of the contacts accompanied by extreme ease of reading the record is thus made possible, and the accuracy of the device is high. It

(180) M. J. Sweet. A Fluorescent Lamp Voltage Stabilizer. *Electronics*, Vol. 13, August 1940, pages 60 and 62.

(181) Anon. Johnson's Direct-Reading Torsion Meter. *Engineering*, (London), Vol. 92, 1911, pages 605 and 606.

(182) D. F. Miner and W. B. Batten. Use of Oscillograph for Measuring Non-electrical Quantities. *Journal American Institute of Electrical Engineers*, Vol. 48, 1929, pages 126-129.

(183) (General Electric Company.) New Aircraft Indicating Instruments. *Instruments*, Vol. 4, 1931, pages 129-130.

(184) H. Olken. Electrical Telemetering. *Instruments*, Vol. 5, 1932, pages 66-74.

(185) H. L. Curtis and R. C. Duncan. The Use of the Oscillograph for the Study of Ballistic Problems. *Physical Review*, Vol. 49, 1919, pages 183-184.

(186) H. L. Curtis. Use of an Oscillograph in Mechanical Measurements. (Discussion.) *Transactions American Institute of Electrical Engineers*, Vol. 44, 1925, pages 264-274.

(187) R. Sulzer. Recent Developments in Diesel Engine Construction: Electro-photographic Vibration Recorder. *Transactions Institution of Engineers and Shipbuilders in Scotland*, Vol. 76, 1932, pages 160-204.

(188) Anon. Recording Hydraulic-Turbine Governor Operation. *Power*, Vol. 58, 1923, pages 446-447.

(189) E. A. Tulus. Tests on Mercury-arc Portable Sub-station Car. *Instruments*, Vol. 7, 1934, pages 158-159.

(190) L. F. Hunt. Some Practical Measuring Devices. *Transactions American Institute of Electrical Engineers*, Vol. 59, 1940, pages 765-768.

can of course be applied to either linear or rotatory motion. Fig. 85 illustrates the connections involved; below the circuit diagram is sketched the pattern recorded by the oscillograph. In this circuit the starting contact ("0") is so connected as to provide a deflection greater than that of any other, and the beginning of the record is therefore easily located.

Moving-contact (or contact-closing) gaging elements in series circuits have been used to indicate or to control large movements up to hundreds of feet. In mine shafts, electrical contacts attached to air-actuated diaphragms have been employed to indicate the position of the moving cage in the

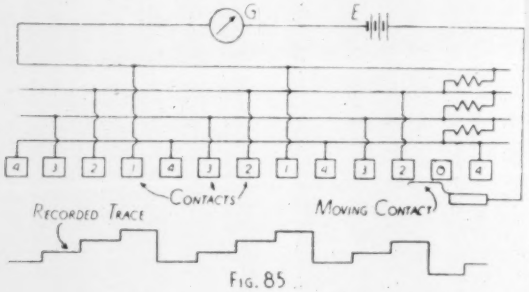


FIG. 85

shaft[191] as the rush of air ahead of the moving cage closes the contacts upon which it impinges. Water levels are controlled in reservoirs through relays actuated by contacts which are controlled by the water level itself. The circuit employed is shown in Fig. 86; as each contact in its turn is closed the total resistance of the circuit is reduced and the current flowing is increased. (With the resistance values shown, each contact adds 0.003 amperes to the total current flowing.) At the receiving end of the system a number of relays are connected in series, so adjusted as to close in succession as the current is increased. In the practical installation, there is one relay at the receiving end for each contact at the transmitting end, and an extra relay

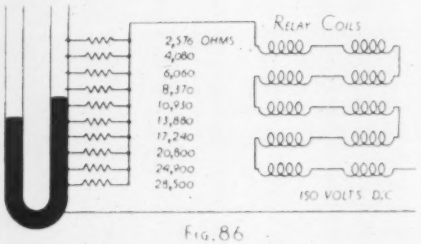


FIG. 86

in a time-delay circuit to prevent contact chatter. The system operates over a telephone line several miles long; it requires only a few milliamperes of current at 150 volts potential.[192]

Contact-making devices used as detectors of position of an object, while a special case, should be described with series circuits. Although not in general use for precise measurements, such devices can be applied to measurements of the highest accuracy.[193] More commonly, however, contact-making devices are employed with follow-up mechanisms for control or recording of movements.[194]

Series circuits are most often used with moving-contact variable-resistance elements, since the resistance variation in these elements is from a minimum of zero to a maximum value equal to the total resistance of the element. With thermosensitive elements they are used only infrequently; these and stress-sensitive elements are more effectively served by bridge or potentiometer circuits.

(191) Anonymous. Ein neuer elektrischer Tiefenanzeiger fuer Fordereranlagen. *Elektrotechnische Zeitschrift*, Vol. 51, October 2, 1930, page 1405.

(192) E. E. Norman. Resistors Watch Level in Water System Reservoir. *Electrical World*, Vol. 120, 1943, pages 635-637.

(193) P. E. Shaw. An Electrical Measuring Machine. *Proceedings Institution of Mechanical Engineers* (London), April 1913, pages 579-629.

(194) L. A. Ware. Water-level Indicator. *Electronics*, Vol. 13, 1940, pages 23-25.

2. Null Bridge Circuits.

Bridge or balanced circuits are the most sensitive of circuits for measuring resistance, and are capable of highest accuracy. For these reasons, they are best fitted use with variable-resistance elements of the thermosetive or stress-sensitive types, in which the resistance chais small. Greatest accuracy with bridge circuits is secby the null methods, although these are much less rapi operation than the deflection bridge circuits.

The principle of the null method is to balance two trical magnitudes against each other until the indicat instrument shows that current no longer flows; the va of the unknown magnitude is then computed from the tions of the known elements in the circuit. The accura of the method depends primarily upon the accuracy of standard components employed. The energizing current potential) need not be constant, or even known; nor the exact sensitivity of the indicating instrument affect result. Because the current flowing through the indicat instrument is never more than a small fraction of th through the rest of the circuit (and at balance is ze high sensitivity can be provided, either by employing la exciting currents or by employing instruments of high rent sensitivity.

The most widely used form of bridge circuit is Wheatstone, a network of six conductors. The form of th circuit is shown in Fig. 87. The "arms" of the bridge cuit are indicated by R_1, R_2, R_3, and R_4; E represents source of electric energy; and G the indicating (or in case *detecting*) instrument which may be an uncalibrat galvanometer. The circuit deriv its name from the fact that the i dicator or galvanometer "bridges the midpoint of the measur arms, and it is a characteristic such circuits that at balance th source of energy and the indica ing instrument can be interchang without affecting the balance of th circuit.

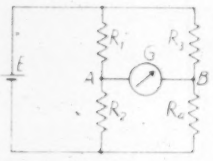


FIG. 87

Another characteristic of bridge circuits, and one whic bears directly upon their applicability to gaging applica tions, has to do with errors due to connecting lead Changes in length or resistance of the leads connecting th bridge circuit to the source of electric energy and to th indicating instrument introduce no error if the circuit used in a null method, and only second-order errors if deflection method is used. This is in contrast to the cond tion obtaining in a series circuit, in which all resistance whether in connecting leads or elsewhere, act in producin an instrument indication.

The operation of the circuit can be deduced from th figure; at balance, no current flows between points A an B (the condition of balance), the potential drop across R equals that across R_3, and that across R_2 equals that across R_4. If no current flows through G, the currents through R and R_2 must be equal, as must be those through R_3 and R This condition can exist only when

$$R_1/R_2 = R_3/R_4$$

(If source and detector are interchanged, the relation becomes $R_1/R_3 = R_2/R_4$ and mathematically the two relations are equivalent.) For greatest sensitivity in use, it necessary that the impedance of the balance-detecting instrument bear the proper relation to the impedances of th arms of the bridge circuit. In most resistance-type gaging circuits the impedances of the detector and of the bridge arms are nearly equal.

In the application of the basic Wheatstone circuit to electric gaging, it is necessary to consider the form and the action of the gaging element. For example, in an installation designed to measure extremely small changes in liquid level, the primary element was a resistance-ratio moving contact element, consisting of two bare resistance wires dipping into the mercury in the two arms of a U-tube manometer. This element was connected into the circuit in th

Continued on page 68.

ELECTRON TUBES—Their Principles and Their Instrumentation Applications

By ANDREW W. KRAMER, Managing Editor, *Power Plant Engineering*, Chicago, Ill.

XXVII. THE PRINCIPLE OF CONVERSION IN INSTRUMENTATION

The simplest application of electronics, not only in the field of instrumentation but in all industrial and communication applications as well, is in the use of the electron tube as a rectifier. Nearly all electronic instruments involve amplifiers and such amplifiers require a source of comparatively high-voltage direct current. This direct current is usually supplied by diode rectifiers in combination with filter circuits to smooth out the pulsations in the rectified current supplied by the tubes. Such filter circuits were described in a preceding article* and constitute a vital element in every electron tube rectifier circuit.

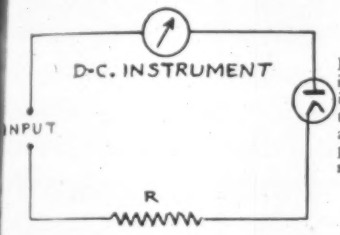


Fig. 181. When a diode rectifier in series with a d-c. instrument is connected across an a-c. circuit, the instrument will read the average a-c. voltage. This is the simplest of all vacuum-tube voltmeters.

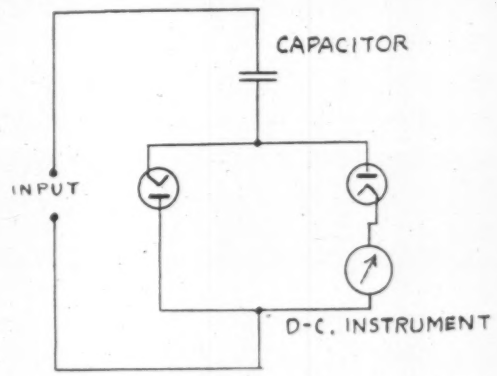


Fig. 182. A simple vacuum-tube voltmeter using two diodes and a capacitor.

When diodes are used in the direct current power supply circuits of electronic instruments, their application is no different from that of any other industrial use where direct current is necessary. A rectifier, however, can perform other functions than as a source of direct current power. For example, a d-c. instrument in the plate circuit of a rectifier will indicate a current which is some function of the alternating voltage applied to the tube. Thus a direct-current instrument may be calibrated as an a-c. voltmeter by merely applying various known alternating voltages on the tube and noting the rectified current passing through the instrument.

A circuit of this kind is shown in Fig. 181. An instrument of this kind will read average voltage. If the diode was a perfect rectifier having zero resistance the meter could be calibrated on direct voltage and used to measure either direct or alternating voltage. Actually, however, the curvature of the diode plate-voltage vs. plate-current characteristic and flow of the plate current when the plate voltage is zero (due to the initial velocity of electrons) the direct voltage readings are different from the a-c. readings. In order to keep the current small it is desirable to maintain a high load resistance and for that reason the resistance R is introduced.

*June 1944.

The circuit shown is the simplest vacuum-tube voltmeter. In this case the tube can be almost any kind of tube, not necessarily a diode. It can be a triode or multigrid type with all electrodes except the control grid connected to the cathode or negative filament. A type 30 triode with a flashlight cell for a filament supply makes a convenient portable unit. The indicator should be, preferably, a sensitive microammeter (0-100 microamps) but an 0-1 milliameter can be used with reduced sensitivity.

Vacuum-tube Voltmeters

The vacuum-tube voltmeter is one of the most generally useful instruments for the measurement of d-c., a-c. and r-f. (radio frequency) voltages. Its principal advantages over ordinary voltmeters are (1) high input resistance (negligible power taken from the circuit under measurement) and (2) good accuracy over a wide range of frequencies, extending with some tubes up into the ultra-high-frequency region.

The type of circuit shown in Fig. 181 is, of course, the simplest of all vacuum-tube voltmeters. The more elaborate

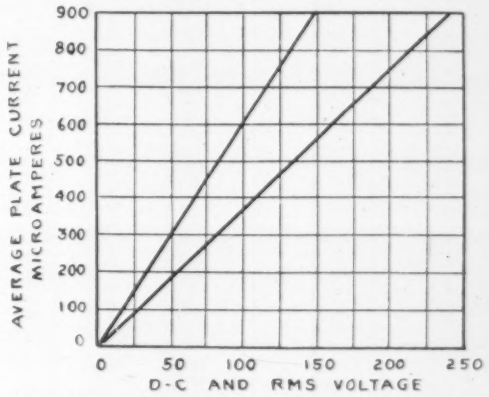


Fig. 183. Calibration curves for the vacuum-tube voltmeter shown in Fig. 181.

ones incorporate more than one tube, some as rectifiers, others as amplifiers to increase the sensitivity of the instruments.

An interesting one, consisting of two diodes and a condenser is shown in Fig. 182. In this case, the condenser current flows through the meter during only half of the cycle so the meter current is unidirectional. With a sinusoidal a-c. voltage wave, the condenser voltage varies between the values E_m and $-E_m$, where E_m is the peak input voltage. The amount of charge that flows into the condensers during half a cycle is 2 CE_m, and the average current through the instrument is equal to the product of this charge and the frequency, or 2 CEF, where F is the frequency in cycles per record.

Simple diode vacuum-tube voltmeters of the type described are of particular value in the measurement of very high voltages when some flow of current is not objectionable. A typical calibration curve for the circuit of Fig. 181 is shown in Fig. 183. Using a large value of R, the calibration curves are sufficiently straight so that in the measurement of high voltage they may be considered straight lines passing through the origins and having slopes as determined by the following equations:

$$\text{For d.c. } E = RI \quad \ldots \quad 1$$

$$\text{For a.c. } E_{av} = 2.22\ RI \quad \ldots \quad 2$$

The circuit of Fig. 181 indicates the average a-c. voltage. If it is desired to indicate the peak value of the a-c. voltage it is merely necessary to place the instrument in paral-

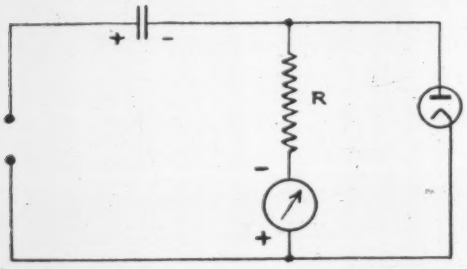


Fig. 184. Vacuum-tube voltmeter circuit which measures the peak value of the a-c. voltage.

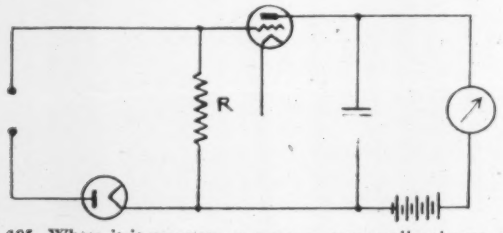


Fig. 185. Where it is necessary to measure very small voltages, the simple circuit of Fig. 181 may be followed by a triode amplifier as shown here.

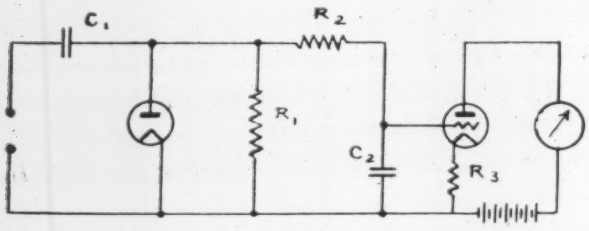


Fig. 186. Another form of vacuum-tube voltmeter circuit incorporating a filter circuit.

lel with the diode and introduce a capacitor into the input circuit as shown in Fig. 184. The input resistance is comparable to that of the simple diode for equivalent sensitivity but the high-frequency error is less. The time constant of the RC circuit should be at least 100 for the lowest frequency to be measured. That is,

$$R\,C\,F < 100$$

where R is the resistance in megohms, C the capacitance in microfarads and F, the frequency in cycles. The resistance R may range from 0.1 to 1.0 megohms.

Where it is necessary to measure very small voltages, the diode circuit of Fig. 181 may be followed by a triode amplifier as shown in Fig. 185. In this case the average plate current of the triode is proportional to the voltage drop across R and this, of course, is a measure of the voltage being measured at the input terminals. If the resistor R is replaced by a capacitor, the capacitor charges to the peak voltage of the positive half-cycle of the applied voltage and the arrangement becomes a peak voltmeter.

A slightly different circuit is shown in Fig. 186. In this case R_2 and C_2 act as a filter circuit to keep the alternating voltage from being impressed upon the amplifier grid. Instruments of this type cannot be damaged by the application of excessive input voltage since the plate current of the amplifier decreases with increase in input voltage.

Degenerative Feedback

A commercial form of the diode voltmeter is shown in Fig. 187A. This is a diagram of the General Radio Type 726-A Vacuum-Tube Voltmeter. As will be noted it resembles the circuit shown in Fig. 186 but has additional refinements. The self-biasing cathode resistor R_3 results in degenerative feedback which gives the amplifier greater stability and results in the calibration being permanent and substantially independent of tube characteristics.

A few words regarding the principle of degenerative feedback may make matters more clear at this point. In an earlier article the principle of positive feedback or regeneration was described. With regeneration, a portion of the output voltage of an amplifier is fed back into the input in such a way that the sum of the feedback voltage and the original signal is greater than the original signal voltage alone.

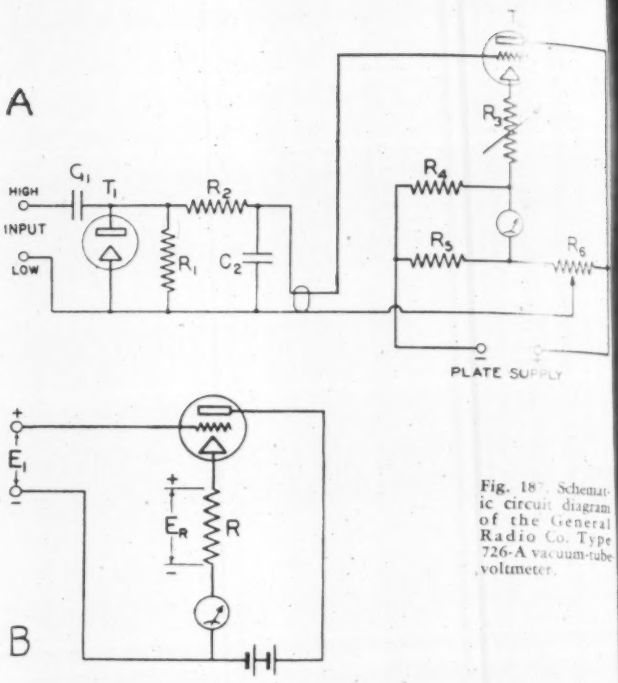


Fig. 187. Schematic circuit diagram of the General Radio Co. Type 726-A vacuum-tube voltmeter.

If, however, the phase of the voltage fed back to the grid circuit of the amplifier is such that the sum of the feedback voltage and the original signal voltage is less than the latter alone, the feedback is said to be negative and the action is termed *degeneration*. With degeneration the total amplification is decreased since the grid signal voltage is made smaller, but the stability of the amplifier will be greatly increased. The gain of the amplifier is made more uniform over a range of frequencies despite the tendency of the amplifier to discriminate against certain frequencies. The detailed action of degenerative feedback circuits is somewhat difficult to explain without recourse to mathematics but if one understands the fundamental fact that it involves the feeding back of a voltage out of phase with the input voltage in such a way that the sum of the combined voltages is less than the input voltage alone, no difficulty should be had in dealing with these circuits.* In the circuit shown in Fig. 187-A the feedback is accomplished by means of the adjustable resistor R_3 in the cathode of the amplifier tube. Fig. 187-B is a simplified diagram of the amplifier circuit in 187-A to show the degenreative effect of the cathode resistor. If a voltage E_1 is introduced into the grid circuit, the plate current will tend to increase causing a voltage drop E_R across the cathode resistor in opposition to the introduced voltage. The net change in grid voltage is the difference between the two. If the cathode resistor is large in value, only a very slight increase in plate current is required to develop a voltage equal to the introduced voltage. The net grid voltage, therefore, can change only slightly, and E_R must always be very nearly equal to E_1. Whenever the cathode resistor is large enough to bring about this condition, the change in plate current, indicated on the instrument, will be directly proportional to the introduced voltage and the tube constants will be of little importance.

The same simple consideration shows that the sensitivity of the arrangement, considered as a d-c. voltmeter, can be changed by varying the cathode resistor. If this resistor is increased in value ten times, only one-tenth of the change in plate current will be required to develop a given opposing

*Further aspects of degenerative feedback will be presented in a subsequent article.

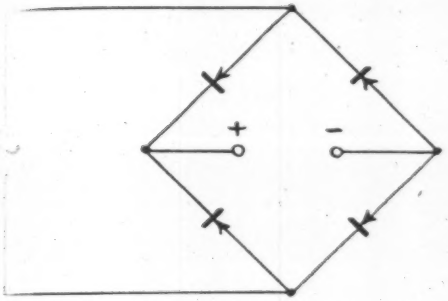


Fig. 188. Copper-oxide type of rectifier used in instruments.

voltage. If the plate milliammeter has a certain full-scale sensitivity, consequently, ten times the voltage must be introduced into the grid circuit to cause full-scale deflection. For sufficiently high values of the cathode resistor, the full-scale voltage is directly proportional to the cathode resistance and depends only on this value and on the sensitivity of the milliammeter.

So much for the principle of degeneration. In the General Radio 726A Voltmeter the diode-rectifier circuit at the left of the diagram uses an acorn tube (955) built into a small probe at the end of a cable. The cable also carries the heater voltage to the tube as well as the rectified voltage being measured. The 955 acorn tube is a triode but it is used as a diode. The amplifier tube, T_2 is a 6Q7. The power supply for the amplifier is not shown but this is supplied through a Type 1-V half-wave high-vacuum diode rectifier. The indicator has a range of 0.1 to 150 volts in five ranges (1.5—5—15—150 V. full scale). The accuracy is 2% of full scale on all five ranges on sinusoidal voltages.

From the foregoing consideration of the diode vacuum-tube voltmeter, it will be seen that the property of rectification in a diode provides a unique way of measuring alternating voltages. The vacuum-tube voltmeter is not confined to the diode, however, indeed the more sensitive forms are based on the use of triodes. These will be described in the article on amplification.

The principle of measuring alternating voltages by d-c. instruments through rectifiers is not confined to the use of tubes alone, however. In recent years, the copper-oxide type of rectifier has been used to considerable advantage for this purpose. By simply connecting a suitably-designed copper-oxide rectifier in series with a direct-current voltmeter, this instrument can be adapted to the measurement of alternating voltages.

The type 492A oxide rectifier manufactured by the General Radio Co. for instrument applications consists of four copper-oxide rectifier units arranged in the form of a bridge as shown in Fig. 188. Each of the four units consists of the type of copper-oxide junction which has the property of unilateral conduction. The bridge is so arranged that two of the junctions pass current on one half-cycle and the other two pass current in the same direction on the other half of the cycle. In this manner full-wave rectification is obtained.

Although high accuracy cannot be obtained when copper oxide units are used and their characteristics do change with load and temperature, they are useful in making ordinary routine measurements. Below 5000 cycles the frequency error is negligible. With the units referred to above, if a 1 milliamper instrument of about 500 ohms resistance is used, a full scale deflection will be obtained with about 2 volts r.m.s. across the input of the rectifier. Such copper oxide rectifiers are widely used in combination a-c. d-c. volt-ohmmeters.

From these few examples, it will be evident that the principle of rectification, though limited in scope, nevertheless has considerable application in the field of measurement. Another use of the rectifier tube is that of an automatic switch, as was described in the previous article in connection with Fig. 180. The 84 type full-wave rectifier in that circuit, it may be recalled, served as a switch for switching the indicator circuit from one side to the other.

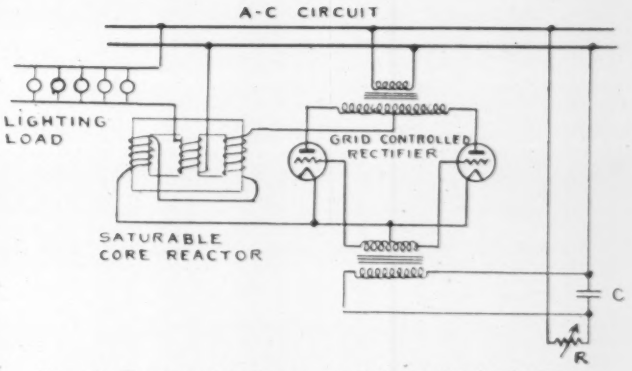


Fig. 189. Circuit used in the control of theatre lighting by means of grid-controlled rectifiers and a saturable-core reactor.

In control systems of various kinds the grid-controlled gas tube (thyratron) proves useful for supplying power from an a-c. circuit. A type of this control is shown in Fig. 189 which is a circuit used in the control of theatre lighting. In this case the alternating-current supply to the lamps is controlled by a saturable-core reactor. Rectified current from the thyratron tubes flowing through the windings on the outside legs of the reactor core causes greater or less magnetic saturation of the core and so controls the alternating current flowing through the winding on the center leg of the reactor. The direct-current output of the thyratrons is controlled by a simple form of phase control consisting of a capacitor and a variable resistor. This circuit changes the phase of the grid voltage in accordance with the setting of the variable resistor. With this form of control, lighting circuits of many kilowatts capacity can be controlled simply by means of a small radio type control knob. In the case of small amounts of power, the saturable-core reactor can be omitted and the lighting current supplied through the tubes.

XXVIII. THE USE OF AMPLIFICATION IN MEASUREMENT

Since the most outstanding function of the electron tube is that of amplifying, it is natural that the electron tube amplifier should find great, almost universal, application in the field of instrumentation. As an amplifier, the vacuum tube extends the degree of sensitivity of almost every fundamental method of measurement.

As in the case of rectification considered in the preceding article, the most fundamental application of the principle of amplification in instrumentation is in the use of the triode as a vacuum-tube voltmeter. In this case the tube functions directly as an amplifier of the voltage being measured.

A simple circuit is shown in Fig. 190. This is known as a grid rectifier type of voltmeter; it may be considered equivalent to the diode of Fig. 184 followed by a zero bias triode amplifier. The advantage of this circuit over that of Fig. 184, however, is that its sensitivity is greatly increased. The input resistance is low with small inputs (0.1 to 1.0 megohm) because of grid current. This circuit is useful because it can be used with inexpensive instruments and can be calibrated from a known 60-cycle source. The scale is square-law from small voltages, becoming linear with increasing input. Another advantage is that the plate

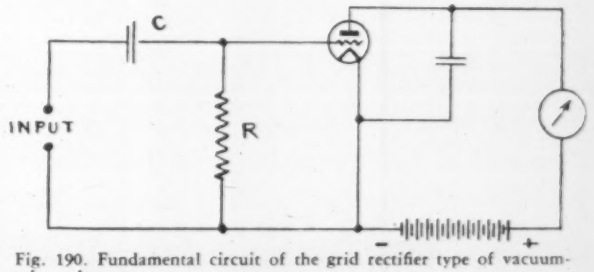
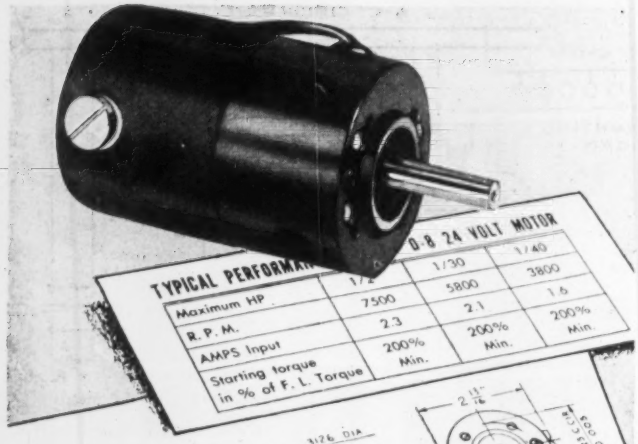
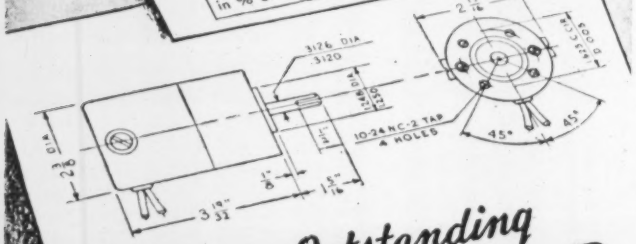


Fig. 190. Fundamental circuit of the grid rectifier type of vacuum-tube voltmeter.





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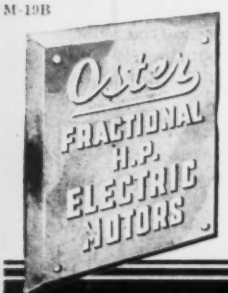

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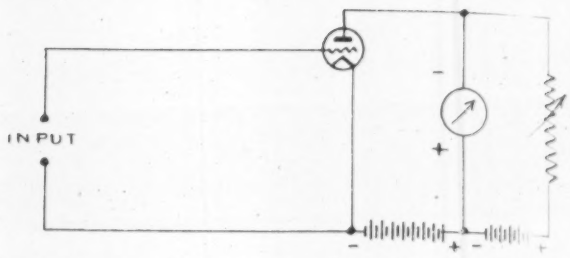

Fig. 191. In the vacuum-tube voltmeter circuit, the no-signal plate current can be balanced out.

current is maximum with zero input, decreasing as the input increases. Thus the instrument cannot be damaged by the application of high voltage.

Further Considerations of Vacuum-Tube Voltmeters

There are a number of vacuum-tube voltmeter circuits available, each having its own peculiar and particular merits but the general principles of operation are more or less the same in all of them. A useful variation is shown in Fig. 191. This belongs to a group in which the no-signal plate current present in the circuits previously described can be balanced out. An auxiliary battery is connected back to the instrument through a variable resistor. This provides a controllable opposite current flow which can be made exactly equal to the residual plate current of the tube.

These vacuum-tube voltmeters are especially useful in the measurement of small audio- and radio-frequency voltage where the use of ordinary voltmeters is unsatisfactory because of the power they consume. As has been explained, the superiority of the electron-tube amplifier over all other forms of electrical amplifiers lies in the fact that the grid draws no electrons when it is maintained at a negative potential. It is evident, therefore, that a vacuum-tube voltmeter properly designed can measure small variations of voltage on the input side without disturbing the input circuit in any way.

A wide-range vacuum-tube voltmeter is shown in Fig. 192. The input tube T_1 is biased to plate-current cut-off. Tube T_2 is connected to the output of T_1 to act as a d-c. amplifier. The type 80 tube provides the d-c. plate voltage for tube T_1, but the plate voltage for T_2 is alternating, taken directly off the primary of the power transformer. Of course, as in any other case where a.c. is applied to the plate circuit of a thermionic tube, the tube itself acts as a rectifier and half-wave rectified current flows in the plate circuit.

A series capacitor C_1 with a shorting switch is provided in the input circuit to isolate d-c. voltages when desired. A shunt resistance R_2 is provided to give the grid a d-c. return when C_1 is used or when the external circuit will not furnish a d-c. path. *Continued on page 690*

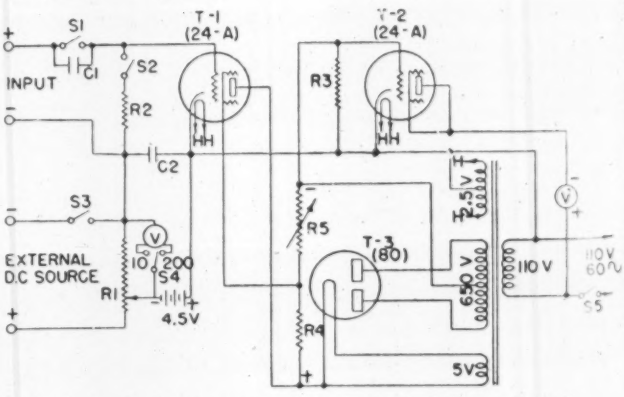

Fig. 192. A wide-range two-tube vacuum-tube voltmeter with d-c amplifier.

C_1—0.001 mfd. mica
C_2—0.001 mfd. mica
R_1—10,000 ohm, 6-watt, wire-wound
R_2—1.0 megohm, 1-watt
R_3—8000 ohm, 1-watt
R_4—15,000 ohm, 10-watt, wire-wound
R_5—2000 ohm, 2-watt, wire-wound

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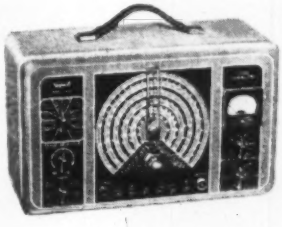

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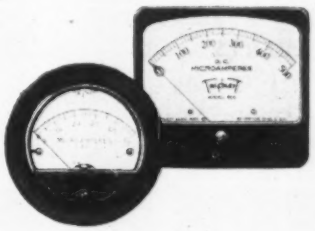

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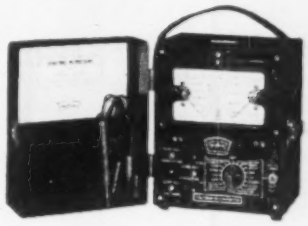

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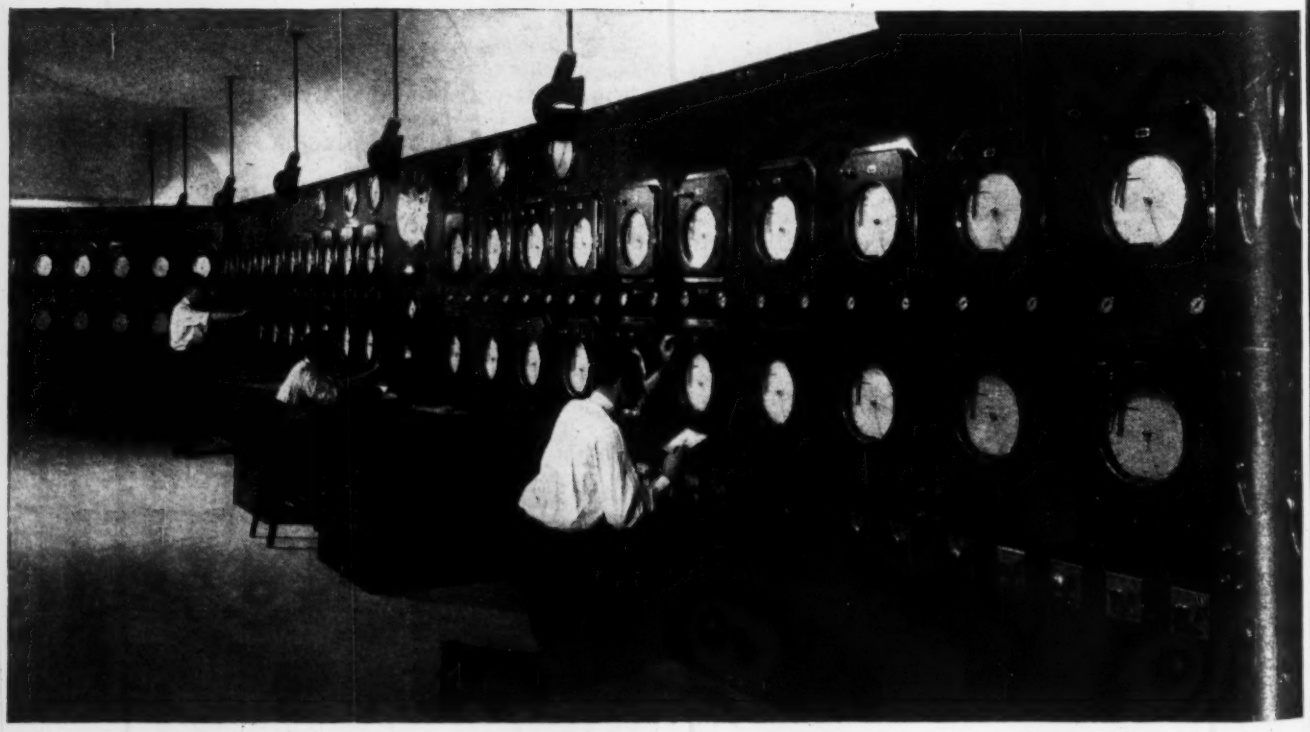

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35

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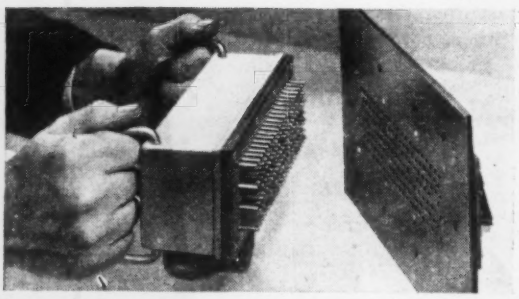

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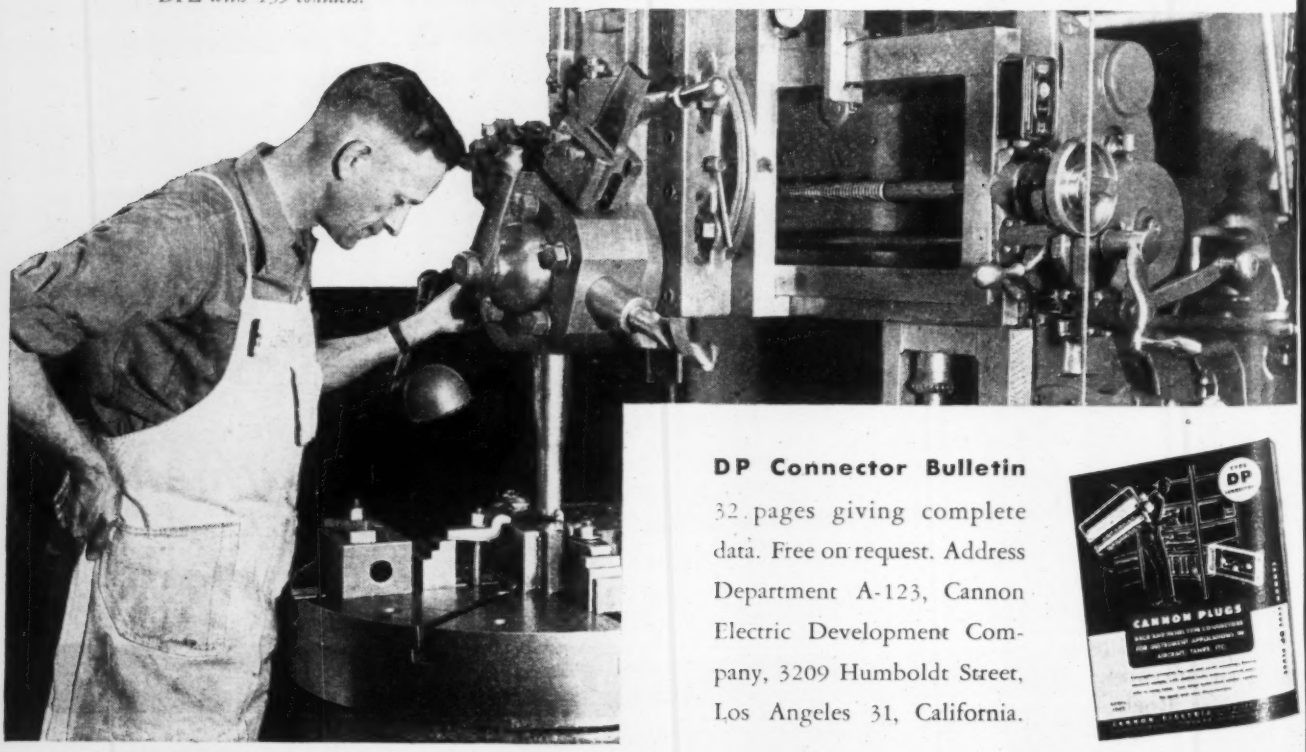

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Vol. III, No. 11 M. F. Behar, Editor November 1944

Suggested Revisions of Part 24 of the Civil Air Regulations—Mechanic Certificates

By JESSE W. LANKFORD, Director, Safety Bureau, Civil Aeronautics Board

THE Civil Aeronautics Board has authorized its Safety Bureau to circulate a proposed revision of Part 24 of the Civil Air Regulations relating to Mechanic Certificates for comment by interested parties prior to final consideration by the Board. The previously proposed revision of this part, which the Board authorized to be circulated in May 1943, received such a meager amount of comment that it could not be considered to represent a fair cross-section of opinion of the industry. Such replies as were received disapproved in general that proposal, particularly with respect to the number of classifications and ratings. They did, however, agree with the need for a substantial revision of the present Part 24. Since that time, considerable study has been given to the subject and discussions have been held with many interested parties, both within the industry and the Civil Aeronautics Administration. The resulting modified proposal which we believe incorporates the features generally desired by both industry and government is appended for your consideration and comment.

Those features upon which your comment is particularly desired are as follows:

1. A mechanic certificate will be issued to any qualified applicant and the attached rating record will show all of the ratings for which the holder has been found competent.

* * * *

4. In addition to the rating for light or heavy aircraft, airframes, and engines, mechanics will be rated further with respect to the following: (a) aircraft maintenance and service, (b) airframe repair and overhaul, (c) engine repair and overhaul.

In an attempt to conform to established practice, no separation with respect to airframe or engine is made in the maintenance and service category. Thus, the so-called "line mechanic" may perform maintenance and service work on any part of the aircraft, whereas such a separation is provided with respect to repair and overhaul. In this manner it is believed that examinations and tests can be provided to cover the particular mechanical experience of an applicant and make it unnecessary for him to be examined on work with which he is not familiar and for which he does not desire a rating. While the radio, instrument, or propeller mechanic will not be examined in any phases of the work which do not directly pertain to his specialty, he will, however, be required to possess sufficient experience and knowledge in his specialty to justify a first class rating.

5. Instead of the previously proposed three classes, mechanics are rated as first class or second class, as determined by the amount of experience. Two classes are considered sufficient since an appropriately rated first class mechanic would be authorized to make the required inspection and to return aircraft to service after major repair, overhaul, or alteration, which authorization heretofore has been available only to an Inspector of the Administrator or to an approved repair station. Furthermore, first class mechanics holding specific authorization from the Administrator may, in addition to the above, make the inspection required for the periodic renewal of the airworthiness certificate. The second class mechanic, within the scope of his category ratings, will have all of the privileges accorded the presently certified aircraft or engine mechanic.

6. Fully realizing that no rating system, however complex, can be made to cover all possible cases and thus prevent a mechanic from performing certain specific operations for which he is not fully competent, we have attempted to avoid many unnecessary rules by the inclusion of the following general service limitations:

24.310 Service limitations. A mechanic may perform duties and assume responsibilities as a certified mechanic only if he is competent by reason of previous experience with, or knowledge of, the particular operation and only if such work is done in accordance with the manufacturer's specifications or the approved Manuals of the Administrator and the details of such work are recorded as prescribed by the Administrator.

* * * * *

In reviewing the attached proposed Part, it should be borne in mind that the rating structure has been prepared on the basis of the needs of the individual mechanic and the small operator rather than on the needs of the large organized repair station or airline maintenance base. It is believed that the large certificated repair stations and airline maintenance bases can be more appropriately handled on the basis of requirements for proper supervision and inspection and appropriate personnel qualifications rather than on the holding of individual mechanic certificates.

We should appreciate having your comment on the proposed revisions not later than December 1, 1944.

EDITOR'S NOTE.—This important proposal deals only in part with instrument maintenance; therefore *Instruments* is omitting portions. Asterisks (* *) indicate every omission. Mr. Lankford's full text is of course available from either the CAB or CAA in Washington. The main difference between these two agencies is that the "Board" deals chiefly with legal matters and the "Administration" with technical matters. We technical men seldom come in contact with CAB officials but most of us know CAA engineers, particularly Mr. O. E. Patton who is a famous specialist in instruments.—MFB

SUGGESTED REVISION OF PART 24—MECHANIC CERTIFICATES

24.0 Issuance

24.00 Mechanic certificate. A mechanic certificate will be issued by the Administrator to any responsible person who demonstrates compliance with the minimum requirements prescribed herein.

24.01 Rating record. A rating record showing one or more category and class ratings for which the holder has been found qualified will be issued in connection with a mechanic certificate.

24.02 Ratings.

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24.020 Category ratings. Category ratings are follows: * * * (h) instruments, (i) radio.

Note: See § 24.5 for definitions.

24.021 Class ratings. Class ratings are as follows:

(a) *Second class.* Issued only for aircraft, airfra[illegible] and engine categories.

(b) *First class.* Issued for all categories.

24.03 Duration. Mechanic certificates will be of [illegible]porary duration for 90 days after the date of issuance du[illegible] which period they may be recalled or changed by the Ad[illegible]nistrator. Thereafter the certificates will have no expiration [illegible]date unless such date is hereafter fixed by the Board. Any suspe[illegible]ed or revoked certificate must be surrendered to the Administrator upon request.

24.1 Minimum requirements.

24.10 Age. Applicant must be at least 18 years of a[illegible]

24.11 Citizenship. * * *

24.12 Knowledge. Applicant must have a general knowledge of construction, functioning, inspection, maintenance, and repair of aircraft, aircraft engines, propellers, or appliances in the categories appropriate to the ratings sought. He must also be familiar with such provisions of the Civil Air Regulations and their Manuals as are applicable.

24.13 Experience.

(a) *2d class ratings.* Applicant must have had at least one year's practical experience or its substantial equivalent with the processes, practices, materials, tools, instruments, and machinery generally used in the inspection, maintenance, service, repair, overhaul, or alteration of aircraft, airframes, engines, or appliances appropriate to the rating sought.

(b) *1st class ratings.* * * *. An applicant for a propeller, instrument, or radio rating must have at least three years' experience or its substantial equivalent with the processes, practices, materials, tools, instruments, and machinery generally used in the inspection, maintenance, service, repair, overhaul, and alteration of that portion of the aircraft appropriate to the rating sought.

24.2 Tests.

24.20 Examinations and tests. Written, oral, and practical examinations * * *.

24.200 Reexamination. * * *.

24.3 Privileges and limitations.

24.30 Privileges and limitations. Any person may perform work on an aircraft provided such work is performed under the supervision of an appropriately certificated mechanic. A certificated mechanic may exercise the following privileges according to his ratings: * * * (h) *Radio.* He may supervise any major repair, overhaul, or alteration of a radio and may return an aircraft to service thereafter if no other portion of the aircraft is involved; (i) *Instrument.* He may supervise any major repair, overhaul, or alteration of an instrument and may return an aircraft to service thereafter if no other portion of the aircraft is involved.

24.31 General limitations. A certificated mechanic when serving as such must have in his possession his mechanic certificate, rating record, and an identification card satisfactory to the Administrator containing his fingerprints, his picture, and his signature.

24.310 Service limitations. A mechanic may perform duties and assume responsibilities as a certificated mechanic only if he is competent by reason of previous experience with, or knowledge of, the particular operation and only if such work is done in accordance with the manufacturer's specifications or the approved Manuals of the Administrator and the details of such work are recorded as prescribed by the Administrator.

24.311 Recent experience. The holder of a mechanic certificate may exercise the privileges thereunder only if, within the preceding 24 calendar months, he has: (a) served as a mechanic for at least six months, or (b) demonstrated to the Administrator that he is able to meet the standards prescribed for the issuance of the certificate and ratings.

24.4 Miscellaneous rules.

24.40 Military competence. An applicant who is, or was within six months preceding application, an active member of the Army, Navy, Marine Corps, or Coast Guard on duty involving regular service as a rated mechanic or specialist technician for a period of not less than one year, upon satisfactory accomplishment of the prescribed written examination on the Civil Air Regulations and presentation of a statement from the appropriate military authorities attesting such rating and experience, will be deemed to have met the requirements for issuance of a mechanic certificate with ratings appropriate to his military rating and experience.

24.41 Existing certificates. A currently effective mechanic certificate will continue in effect for a period not to exceed 18 months after the effective date of this Part, during which time the holder may, upon application, be issued a mechanic certificate and the appropriate ratings provided for in this Part.

24.42 Reports and records required. * * *

24.43 Change of address. * * *

24.5 Definitions.

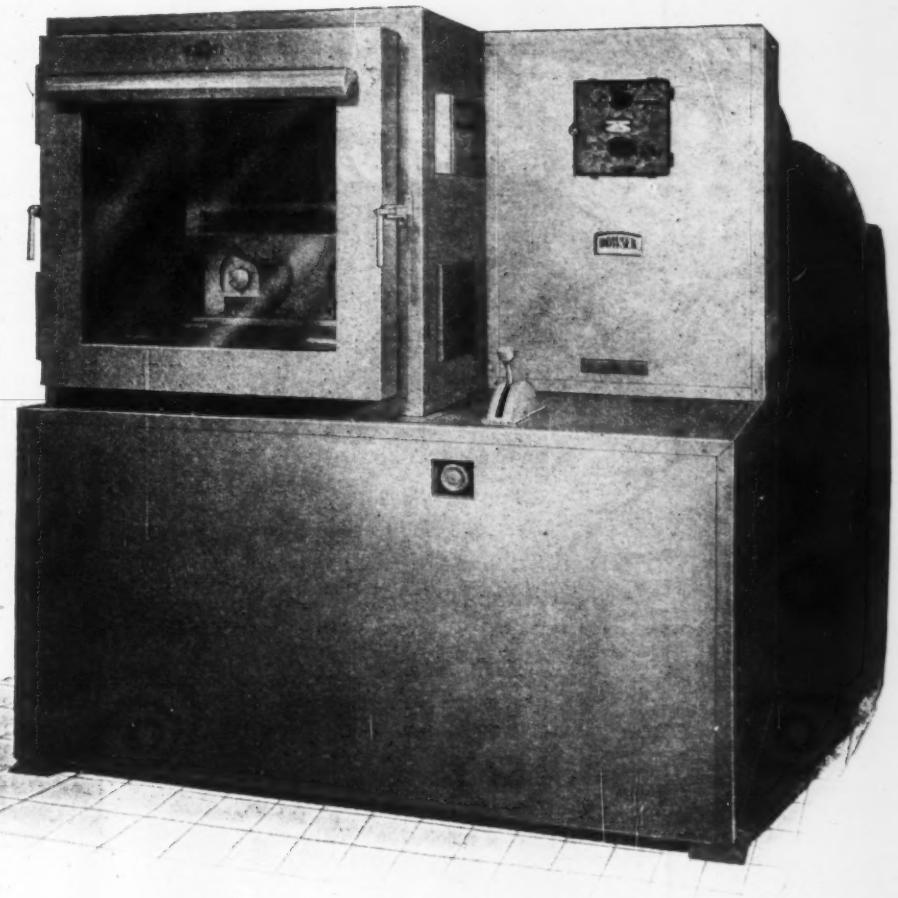
* * * * *

24.506 Maintenance, service, repair, overhaul, and alteration. Maintenance, service, repair, overhaul, and alteration are defined in Manual 18.

HIGHER

than a plane

can fly . . .



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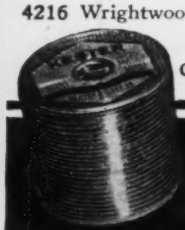

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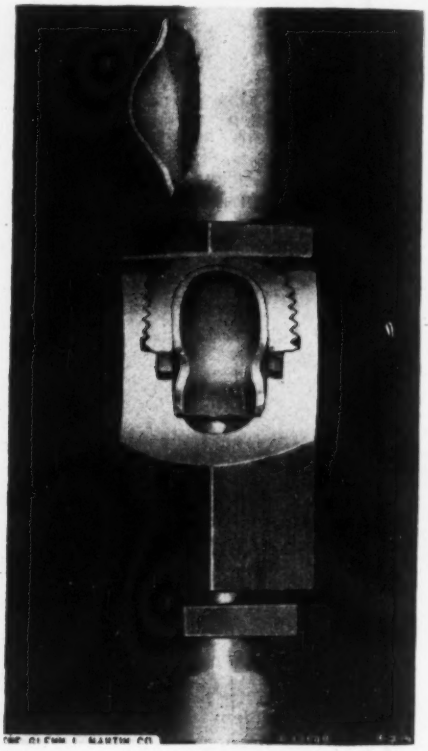
SIMPLIFYING installation procedures in shop and field a new type hydraulic tube connection which obviates the need of tube flaring and provides greater resistance to vibration breakage has been developed by The Glenn L. Martin Co., Baltimore, Md., and is being made generally available through licensed manufacturers. Invented by C. E. Holliday of the Martin Service Engineering Department, the new fitting is simple in design and can be fabricated in large quantities at low cost. Basic parts consist of the fitting, a gland nut, a small metal collar and a synthetic rubber sealing ring. The fitting is bored in four concentric

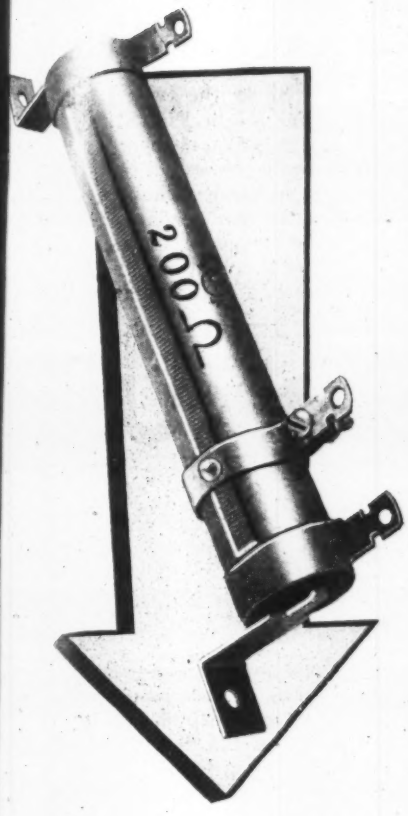


Connected with a new type Martin hydraulic fitting, this piece of ⅜" diameter by 0.049" wall aluminum tube burst under 5,000 lbs./in.² pressure, but the fitting and joint were unaffected. Cutaway portion shows the principle of the new fitting in which a rubber sealing is compressed with such force by turning up the gland nut that it beads the tube and permanently seals the joint.

diameters, corresponding respectively from the center out to the inside diameter of the tube, the outside diameter of the rubber ring and metal collar and the outside diameter of the gland nut, with the outside section threaded to take the gland nut.

To install the new fitting, one simply places the gland nut, metal collar and rubber ring over the end of the tube in that order and inserts the tube in the gland as far as it will go. By turning up the gland nut, force is exerted on the rubber ring with the metal serving to keep the nut from tearing the ring. Since the sealing ring is completely confined, and rubber is not compressible, the axial thrust so developed grips the tube and actually beads it. At the same time, the rubber is forced into every crevice to form a perfect seal and exerts an outward force on the gland nut locking the threads. The beading operation is foolproof in that after the proper bead has been accomplished, the gland nut bottoms in the fittings and further crushing of the tube is impossible.

Torque required to install a ⅜" fitting is 200 in.-lbs. for aluminum and 900 in.-lbs. for steel. Pressure loss due to restriction is negligible by reason of the smooth contour of the restricted area and because of a Venturi-like "recovery cone" in either direction of flow.



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Continued from page 670

manner shown in Fig. 88A, where the two variable-resistance elements replace R_1 and R_3 in Fig. 87. Three leads are needed to connect this primary element to the other parts of the circuit and, as here connected, these leads provide compensation against resistance changes caused by temperature changes. Since the two leads contained with in the measuring arms of the bridge circuit are similar and exposed to the same atmospheric conditions, they will suffer the same changes in resistance, and the balance of the circuit will be unaffected by temperature changes. In all such circuits, lead-resistance error must be compensated, if good accuracy and high sensitivity are desired.

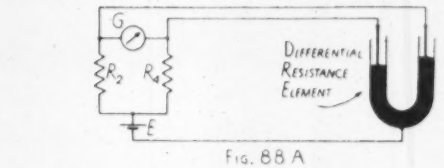

Fig. 88 A

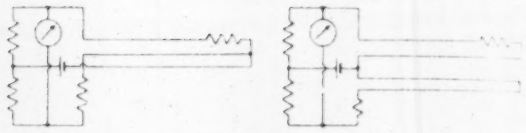

Fig. 88 B

To illustrate the sensitivity of the device just described it may be stated that with it measurements of 0.00003" are possible.[195]

In some locations it is necessary to install single variable-resistance gaging elements at the end of long leads; it is then necessary to provide some other means of lead-length compensation. Two circuits often used in such applications are drawn in Fig. 88B; electrically each of these is the basic Wheatstone bridge circuit, but the mechanical arrangement of the connecting leads is such as to compensate for changes in their resistance due to changes in surrounding conditions. When it is employed in measurement of temperature changes, the active resistance element must be exposed to the unknown temperature, while the other resistors in the circuit are maintained at some known temperature. But when such an element is employed to measure strain the active resistance element alone must be allowed to experience the strain, while the compensating element is insulated from it. In this application temperature changes of the active element must also be applied to the compensating element; otherwise temperature changes can alter the balance of the circuit, and thus appear as strain phenomena.

Many resistance-type gaging elements (especially strain-sensitive elements) experience only a small change in resistance with the applied phenomenon. In order to facilitate the detection of small changes in resistance, the basic Wheatstone bridge circuit can be modified to the Carey-Foster[196] form, shown in Fig. 89. In this circuit two fixed resistors are introduced into the measuring arms, so that the range over which the circuit can be balanced is reduced, but the accuracy of reading is correspondingly increased.* It is convenient to install a shunt in parallel with the slide-wire so that the sensitivity can be adjusted. With such a shunt the slide-wire element can be graduated, for direct reading, and the inevitable small differences in characteristics of the primary elements can be eliminated by adjust-

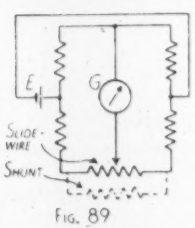

Fig. 89

*In the Carey-Foster method of *measuring* resistance accurately the added resistances are interchanged during the measurement; for *detecting changes* in resistance values this interchange is not necessary.

(195) I. B. Smith. Recording Small Pressure Differences. *Journal Optical Society of America*, Vol. 12, 1926, page 655.

(196) S. G. Starling. Electricity and Magnetism. Longmans Green & Co., 1920. Chapter III.

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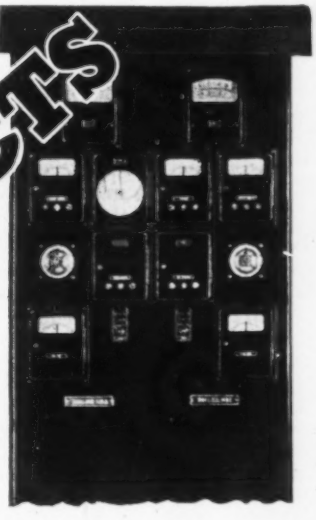

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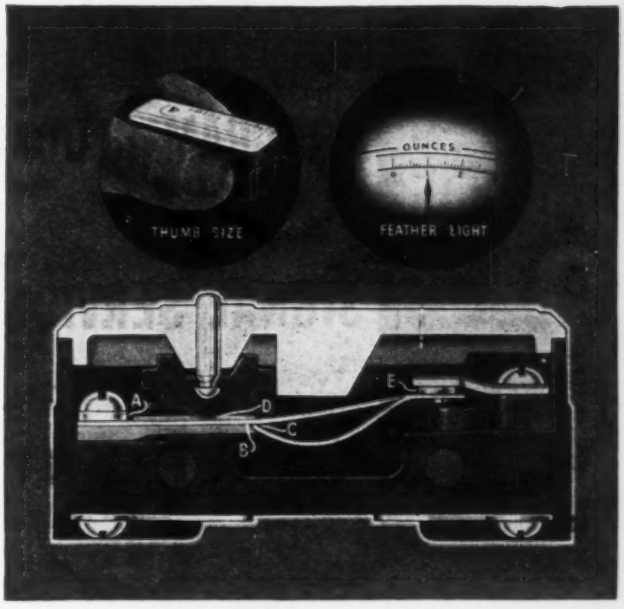

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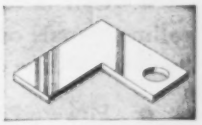

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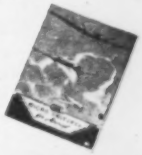

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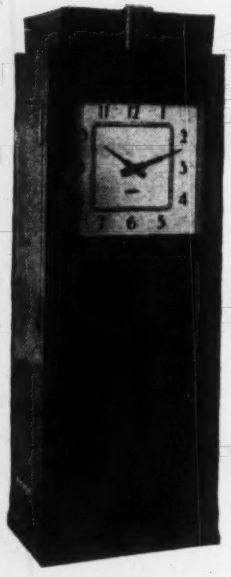

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ment of this shunt. Or, if desired, this shunt can be employed to alter the operating ranges of the circuit.

Instead of a continuously-graduated slide-wire, a series of multiple shunts have been applied to a fixed resistor replacing the slide-wire of Fig. 89. Exact resetting is thus made easy, and the cost of the unit is not excessive.[196] The presence of switches in the balancing arms of the bridge circuit is not desirable, but since the resistances in series with these switches are of large values, the difficulties from this source are minimized.

Another form of shunt balancing has been widely used because of its low cost and its ability to provide a wide range of adjustment. It involves applying a variable shunting resistance across one of the two fixed arms of the bridge circuit, and adjusting this shunt until balance is attained.[198] A switching device must be provided, so that the shunt can be placed across the arms where it is required —the one having too high resistance for balance. This circuit is shown in Fig. 90. The advantages of the method are that it permits balancing over a wide range of resistance values, and that it does not require precision resistors for its construction, excepting the decade shunt resistance unit. Like the other shunt-balance method, however, it places a switching device in a measuring arm of the bridge circuit.

Of the three forms of bridge circuit just described, the slide-wire Carey-Foster bridge circuit, if constructed and applied with care, affords the best results.

Another form of bridge circuit, the Kelvin bridge, a network of nine conductors, is especially applicable to the comparison of extremely low resistances.[196] This circuit is

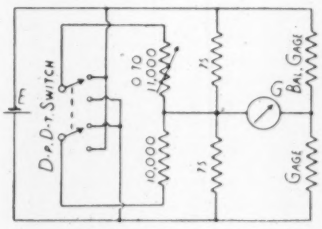

Fig. 90

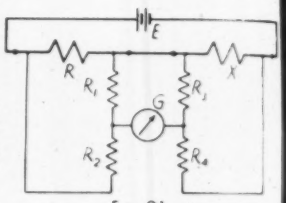

Fig. 91

shown at Fig. 91. It derives its high sensitivity from the fact that the energizing current may be made extremely large, since it does not flow through the network of graduated resistance elements R_1, R_2, R_3 and R_4. (A fixed comparison resistor through which the energizing current flows is required, but this resistor need not be adjustable.) The large energizing current flows through the comparison resistor R and the unknown resistor X in series; changes in the magnitude of the energizing current do not affect the balance of the bridge. The four ratio arms are of high resistance, and small changes in resistance of their leads are of negligible importance compared to similar changes in the current-carrying arms. At balance no current flows through the indicating instrument G, and to achieve this condition the ratio arms R_1, R_2, R_3 and R_4 must be adjusted until the following relation is satisfied:

$$X = R\,(R_4/R_1)$$

while at the same time

$$R_1/R_4 = R_2/R_3$$

In electric gaging practice, bridge circuits of the Kelvin form are useful especially in these two instances: when the specimen itself is the variable-resistance element, and when the variable-resistance element must be attached to a moving number with its electrical connections made through slip-rings.

3. Thermosensitive Bridge Circuits.

The bridge circuits employed with thermosensitive ele-

(197) C. O. Dohrenwend and W. R. Mehaffey. Measurement of Dynamic Strain. *Journal of Applied Mechanics*, Vol. 10, 1943, pages A-85-A-92.

(198) E. S. Carmick and H. B. Dodge. Use of an Electrical Strain Gage in Investigating Stresses. *Journal American Society of Naval Engineers*, Vol. 52, 1940, pages 557-570.

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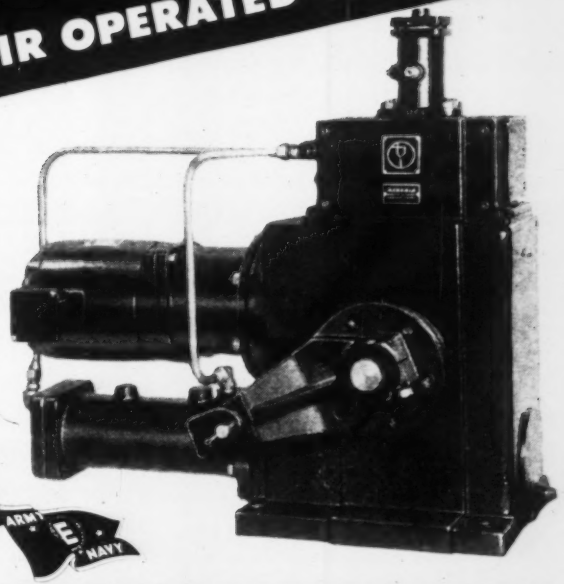

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ments are of two general kinds; they may be termed constant-temperature circuits, or constant-current circuits.

In the constant-current circuit, the electric current which supplies heat to the filamentary resistance element is maintained constant, so that the temperature of the thermosensitive element likewise remains constant (and the circuit remains in balance) unless the element is exposed to some phenomenon which can change its temperature. When this occurs, the rate of heat transfer from the element is altered and consequently its temperature and its resistance also change. The bridge circuit must then be balanced by altering the resistance of the graduated arms of the bridge until the indicating instrument shows that a condition of balance obtains; the change in resistance required then represents the magnitude being measured. A circuit in which the same source of electric energy is used both for heating the thermosensitive elements and for exciting the bridge circuit is shown in Fig. 92A. In this diagram, a current-measuring instrument is placed in the same portion of the bridge circuit as is the gaging element, and by means of this instrument the heating current is kept constant. It is not unusual, however, as shown in Fig. 92B, for the current to be controlled by a non-linear bridge unit without any separate provision being made for observation of its value. In such an arrangement, the two opposite arms of the bridge circuit are made of material with negligible temperature coefficient of resistance, so that the current through them remains constant.

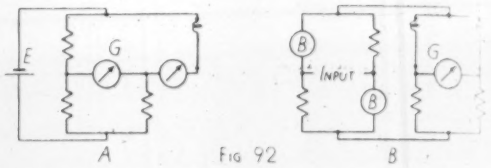

Fig. 92

In the constant-temperature circuit, the bridge unit contains no provision for making a resistance balance during operation excepting through change in the heating current flowing through the thermosensitive elements. Any change in the rate of heat dissipation from these elements, therefore, will destroy the balance of the circuit and, to restore this balance, the heating current must be adjusted until the indicating instrument shows no deflection. The change in rate of heat transfer from the thermosensitive element is therefore represented by the change in the amount of electric energy introduced, and may be observed upon the current-measuring instrument. A circuit by which this may be accomplished is shown in Fig. 93.

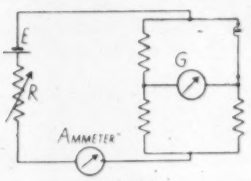

Fig. 93

The constant-current circuit is frequently employed when the unit is to be used as a deflection bridge: if a constant-current supply is made available the device can be made direct-reading or can be made to record its output upon a graphic instrument—a moving-chart recorder or an oscillograph, depending on the required speed.

The constant-temperature method is most used when it is essential that the instrument impart no heat (or a known and constant amount of heat) to the subject of the measurement. The kata-thermometer, which measures rate of cooling from a known temperature, embodies one application of this circuit.[199]

To be continued

(199) British Medical Research Council. The Kata-thermometer in Studies of Body Heat and Efficiency. His Majesty's Stationery Office, London, 1923. Part I, Appendix I.

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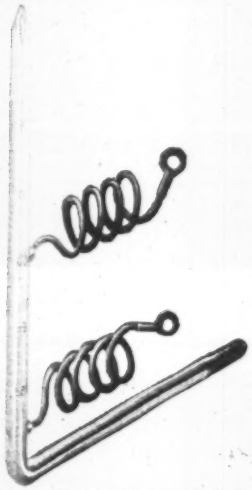

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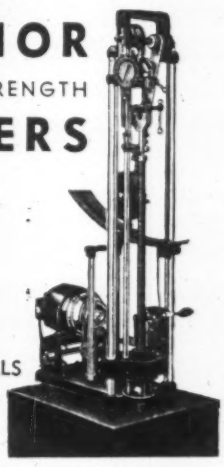

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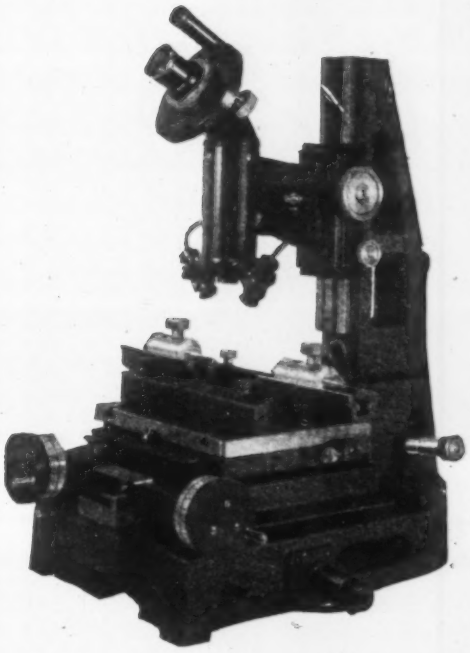

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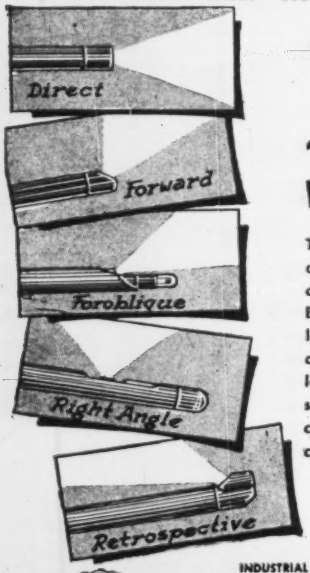

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Continued from page 674

Voltage divider R_1 provides the means for a[djusting] external d-c. source so as to give the negati[ve] potenti[al] necessary to balance the voltage being measure[d]; the val[ue] being indicated by the two-range d-c. voltmete[r]. A sm[all] 4½-volt "C" battery is wired into the input. [Its] purpo[se] is to bias tube T_1 to the plate current cutoff. V[ernier] a[d]justment of the plate current cutoff is accom[plished] [by] variation of the screen grid voltage, using R_5 as a contr[ol].

R_3 forms part of the output circuit of tube T_1 as w[ell] as the input circuit to T_2. With T_1 operating near cut[off] the d-c. voltage drop across R_3 is small. With no input vol[t]age to T_1, tube T_2 will be operating at maximum pla[te] current which will be indicated by the milliammeter in t[he] plate current of this tube. A very small increase in pla[te] current of T_1 due to a small voltage applied to the inp[ut] will cause a relatively large increase in voltage drop acro[ss] R_3. This, in turn, will cause a sharp reduction in the d[e]flection of the milliammeter in the plate circuit of T_2. B[y] adjustment of R_1, the milliammeter pointer can be brou[ght] back to its original reading or "false zero."

This vacuum-tube voltmeter is representative of a who[le] class of circuits which use the amplifying or rectifyi[ng] properties of tubes for this purpose. It is applicable to t[he] measurement of voltages of all types, direct or alternati[ng] low or high frequency.

At the A. O. Smith Corp. in Milwaukee, the electron-tub[e] voltmeter solved a rather difficult problem of measuring t[he]

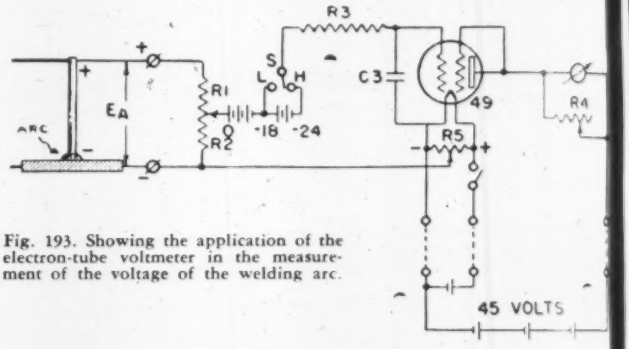

Fig. 193. Showing the application of the electron-tube voltmeter in the measurement of the voltage of the welding arc.

voltage across the arc in electric welding processes. In electric arc welding the length of the arc is an importan[t] factor in the production of uniform welds and since the voltage across the arc is a direct function of the length it becomes desirable to check this voltage continually, especially in training new men and for setting automatic welding heads. It has been found that the voltage change occurring when the arc changes from the correct to an incorrect length is rather small; furthermore, the open-circuit voltage of the welder is usually twice the voltage when the arc is struck. Both of these factors make voltage measurements of the arc difficult with ordinary voltmeters, so the electron-tubbe voltmeter circuit shown in Fig. 193 was worked out by W. Richter and this gives very satisfactory results in this service. As will be noted, it is a simple circuit using a single 49 dual-grid power amplifier supplied entirely by dry batteries. By means of the voltage divider R_1 R_2 only half of the arc voltage variations are impressed on the tube. A "C" battery is provided for varying the bias on the tube so that different ranges may be obtained. As shown, with two taps on the "C" battery, the instrument covers a total range of 20 to 44 volts in two steps.

These vacuum-tube voltmeters will serve to show the principles involved in this type of work. These circuits are particularly valuable in the measurement of extremely weak voltages and where the variations are small. In the measurement of high-frequency voltages, the voltages are merely amplified and rectified so that they can be measured by a d-c. voltmeter; in fact, there is no other way of measuring high-frequency voltages.

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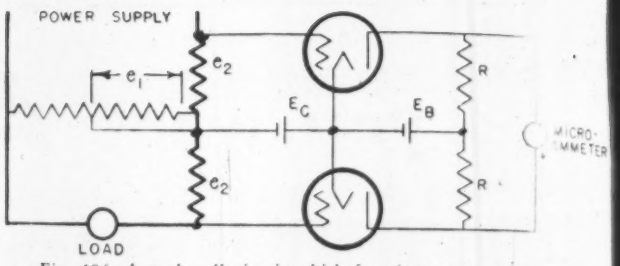

Fig. 194. A push-pull circuit which functions as a wattmeter for the measurement of small power.

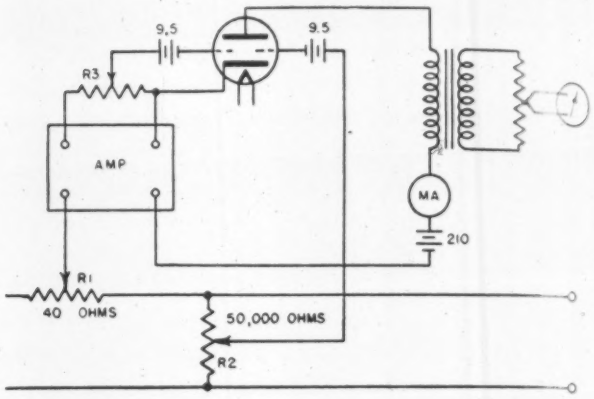

Fig. 195. Another electron tube wattmeter circuit using a tube with two symmetrical control grids.

Electron Tube Wattmeter

The principles involved in these voltage-measuring circuits are subject to almost infinite variation and modification. The idea of measurement, of course, implies control and in many instances these electron-tube voltmeter principles have been applied in control systems. In special cases, the electron-tube voltmeter idea has been incorporated in an electron-tube wattmeter for the measurement of extremely small power. In one instance of this kind a push-pull circuit such as that shown in Fig. 194 has been used. The load current is measured by the voltage drop across a small resistance in series with the line and the load voltage by the drop in high resistance across the line. The sum of the instantaneous values of the two component voltages is impressed on the grid of one tube and their difference on that of the other. The microammeter in the plate circuit measures the power supplied to the load directly.

Another interesting wattmeter circuit has been devised by T. B. Wagner by the use of a double-grid tube. As shown in Fig. 195, this tube has two symmetrical and therefore equally effective control grids. A voltage proportional to the load current is impressed on one of the grids while the voltage across the load is impressed on the other. In this way the measuring instrument in the plate circuit is made to indicate the power in watts; indeed, it has been found that it will operate not only as a wattmeter but will give voltage, current or power factor as well.

Direct-current Amplifiers

It is obviously impractical to attempt describing all the amplifier applications in the field of measurement in a work such as this. Electron-tube amplifiers can be used to amplify weak voltages or currents for almost any purpose necessary. Various forms of portable amplifiers are available for industrial uses. Fig. 196, for example, is an a-c.-operated direct-current amplifier. Its main function is to

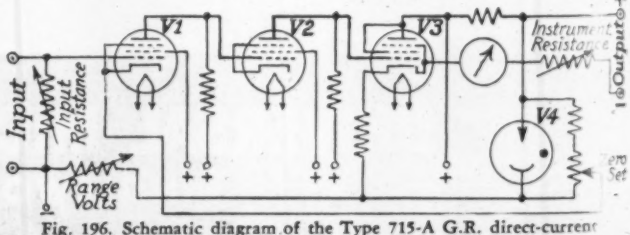

Fig. 196. Schematic diagram of the Type 715-A G.R. direct-current amplifier.

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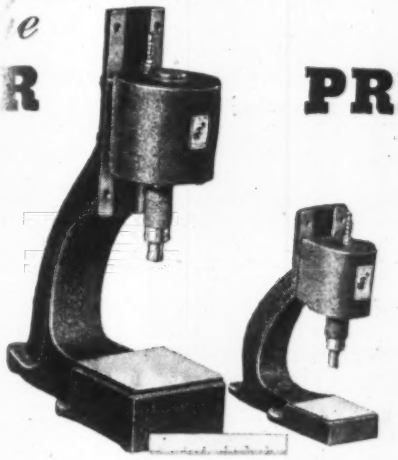

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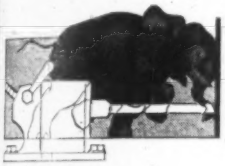

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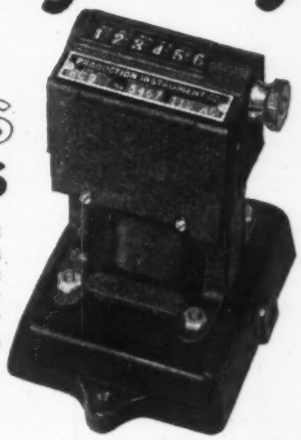

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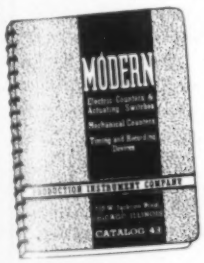

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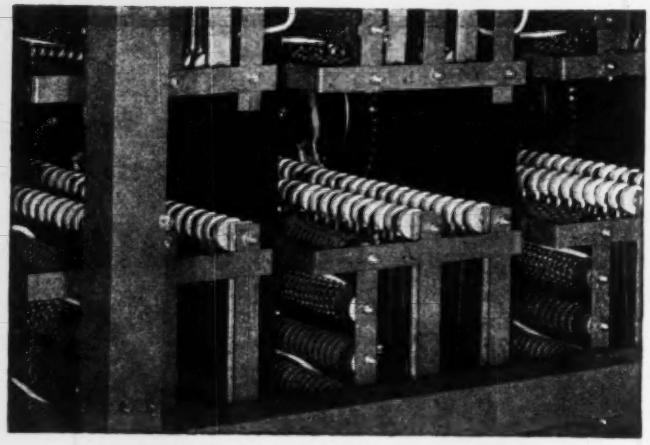

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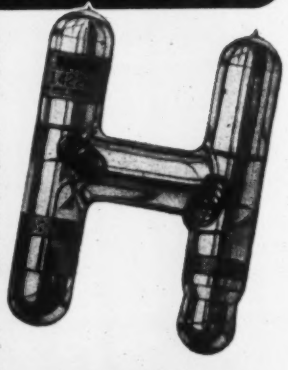

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effectively increase the sensitivity of direct-reading or recording instruments. Used with indicating instruments, it makes possible the use of rugged instruments for indicating small voltages and currents instead of the delicate high-sensitivity instruments which would otherwise be required. Recorders, because of the higher power required to operate them, cannot be used on weak currents and voltages without an amplifier. The amplifier, therefore, extends the use of these instruments to fields formerly beyond their scope, permitting continuous records of sound level, light intensity, frequency, and other phenomena.

The d-c. amplifier shown in Fig. 196 is a useful versatile instrument. An important use is in automobile control circuits where, instead of being used to operate an indicating or recording instrument, the amplifier output actuates relays to control the original phenomenon or to perform some other function. This particular model is the General Radio Type 715A and is of interest because its operation from alternating current is achieved with no loss in stability and with complete freedom from fluctuations due to line voltage variations within reasonable limits. Like the vacuum-tube voltmeter previously described it makes use of degeneration to stabilize the amplifier gain and to improve the linearity of response. In Fig. 196 the power supply circuit is omitted. An instrument of this type can be used for continuous recording. It will operate for weeks without attention except for a daily check of the zero adjustment which takes perhaps a half minute. The tubes have a life expectancy of better than 3000 hours (120 days) when used continuously.

Amplifiers and Recorders

One of the most important uses of this amplifier is in recording work. Full-scale output of the amplifier has, therefore, been made 5 milliamperes to operate an Esterline-Angus high-sensitivity recording instrument which requires 5 milliamperes for full-scale deflection. Although the instrument should be considered as a voltage-operated device, its extreme sensitivity as a current amplifier is quite remarkable. One-tenth of a volt input will give full-scale deflection in the 5-milliampere output circuit. A current of only 0.01 microampere passed through the 10 megohm input resistance will provide this one-tenth volt input.

In conjunction with a sound level meter and a recorder, the amplifier can provide a continuous record of average noise or sound levels over long periods of time. Also, because of its high input resistance it can be used in the recording and measurement of hydrogen ion concentration with low-resistance electrodes. Comparatively weak radio telegraph signals can be recorded on tape recorders by the use of a small oxide rectifier, the d-c. amplifier and a recorder.

Another extremely important application is its use in connection with photoelectric devices. It can be made to operate directly from the output of a "Photronic" cell and when so used and with a recorder, a number of applications are possible since the illumination of the photocell can be made to vary in accordance with such a large number of factors. These include:

1. Variations in daylight;
2. Variations in artificial light brought about by smoke or dust in the air
3. Amount and duration of sunshine

There is, in fact, almost no limit to the uses of an amplifier of this kind. For some applications, the amplifier may serve in place of a sensitive direct-current galvanometer. Using a one-megohm input resistance, the amplifier has a sensitivity of the order of 0.0004 microampere for one-fifth of a division on the indicator's scale, comparing with a good grade galvanometer having a sensitivity of 0.0005 microampere per mm. at 1 meter. The indicator on the panel of the amplifier gives a high-speed response where the galvanometer has roughly a 10-second period.

Measuring Time Intervals

Typical of the applications to which electron-tube amplifiers can be adapted is the one shown in Fig. 197. This is an electron-tube chronograph, used to regulate watches and

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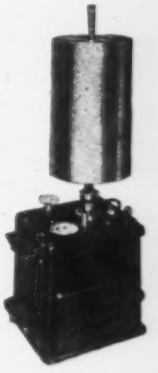

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DRUM or cylinder is all-aluminum, 6.25" diameter and 10" tall. Takes charts 10" by 20". Can be used with low cost attachment for endless charts up to eight feet long. Drum shaft is 22 inches long and drum may be placed any height on it. A rigid inner shaft also supports the drum on ballbearings.

STEEL HOUSING is welded. Protected inside and out with baked enamel. It houses motor, drive, indexing and gear shifting mechanism. There are two projecting lugs to hold ½" diameter vertical rods for instruments or your own appliances.

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SPEED CHANGING is accomplished by turning knob. Every MONODRUM has 20 geometrical speeds. Each speed is 5/8 as fast as the one preceding. Dial on top always indicates speed selection in use.

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Write today for folder on MONODRUM. Ask also for booklet "A Second or a Decade" showing other unusual apparatus for recording or chart moving.

MONO-DRUM SPEEDS

Speed	Synchronous Cm/min	RPM	HiSpeed Cm/min	RPM
A	572	11.4	2,000	40
B	354	8.4	1,250	25
C	221	4.42	780	15.6
D	130	2.60	487	9.7
E	87.7	1.74	304	6.0
F	54.2	1.08	190	3.8
G	21.0	0.42	109	2.1
H	13.2	0.26	74.4	1.48
I	8.25	0.16	46.5	0.903
J	5.15	0.103	29.0	0.58
K	3.22	0.065	18.3	0.36
L	2.05	0.040	11.3	0.22
M	1.26	0.025	7.10	0.14
N	0.785	0.0157	4.43	0.098
O	0.492	0.0098	2.77	0.055
P	0.306	0.006	1.73	0.034
Q	0.193	0.0038	1.08	0.020
R	0.119	0.0023	0.634	0.012
S	0.0747	0.0015	0.398	0.007
T	0.0467	0.0009	0.251	0.005

Synchronous MONO-DRUMS run at dead accurate speeds. Slowest speed is 17.8 hours per one revolution of the drum.

HiSpeed MONO-DRUMS turn one revolution every 3.3 hours at slowest speed.

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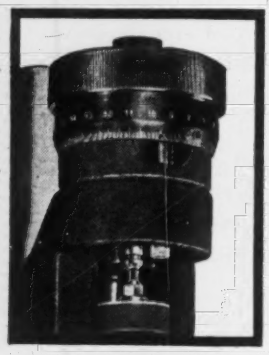
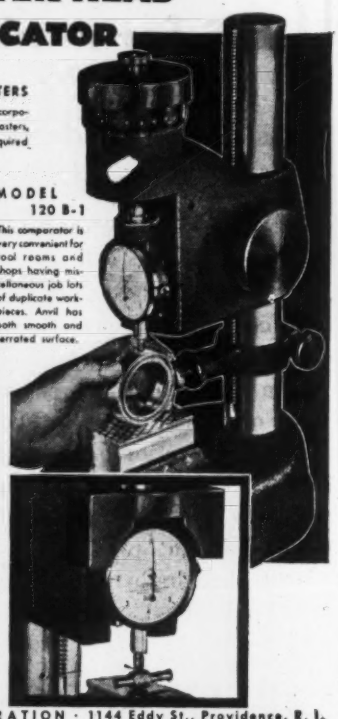


MODEL 120 B-1

This comparator is very convenient for tool rooms and shops having miscellaneous job lots of duplicate workpieces. Anvil has both smooth and serrated surface.



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is easy on this new comparator because the Micrometer Head enables you to read the actual dimension of the Pitch Diameter. The Dial Indicator then compares the diameters of other similar screw threads. The weight over the Indicator is for coarse threads.

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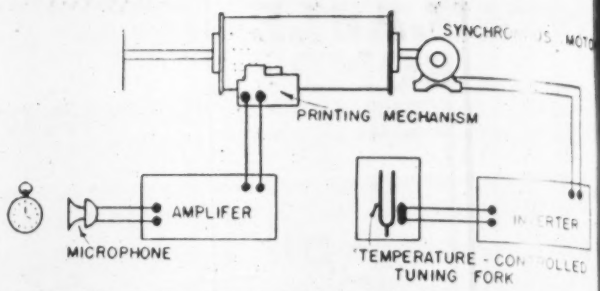

Fig. 197. An electron-tube chronograph for the accurate measurement of short time intervals as is necessary in checking the accuracy of time pieces.

clocks. All of us, at one time or another, have had a watch or clock at the jeweler's for regulation. Usually this took time—several days or a week, even longer.

With a new chronograph system developed by Charles Young and Maurice Artzt of the R. C. A. Manufacturing Co., however, a watch can be accurately regulated in a few minutes 'time by measuring the interval between ticks. It consists of a tuning fork, accurately temperature-controlled, controlling the speed of a driving motor connected to a drum on which a visible record is made. The watch ticks are amplified after being picked up by a microphone and by means of a printer are recorded on a paper chart. Since the tuning fork serves as a time frequency standard, the intervals between ticks may be determined with great accuracy. The time-keeping capacity of a watch may be determined to an accuracy of within 1 second a day in about 1 minute. An application such as this is, of course, quite outside of the ordinary run that might be encountered in industrial work, but it demonstrates the versatility of the electron tube. Electron tubes play their part at both ends of the system, first in the amplifier which amplifies the weak impulses of the microphone to a degree such that they are able to operate the printing mechanism and second in converting the impulses of the tuning fork into alternating current for operating the synchronous driving motor. Fundamentally, the idea is very simple but it was quite impossible of attainment until the advent of electron tube amplifiers and rectifiers.

Quite different from the timing devices just described is a viscosity tester using electron tubes. In some manufacturing processes heavy viscous liquids are used and it is important that the viscosity of these liquids be maintained uniform. To test the viscosity of these liquids, the simple arrangement shown in Fig. 198 has been found very effective. It consists of an inclined glass tube surrounded by two coils connected as shown and in which the liquid to be tested is placed. A heavy steel ball is rolled through the liquid in the tube and as it passes through the coils it causes two successive clicks in a pair of headphones or two sudden movements of the pointer of a plate milliammeter. The time interval between the clicks is then a function of the viscosity of the liquid and it can be checked with a stop watch.

Use of the Capacitor Discharge Circuit

Because of its all but limitless sensitivity and its inconceivable speed of action, the electron tube amplifier in many instances can accomplish things that cannot possibly be accomplished without tubes. This is particularly true in the field of control. Control is really an extension of measure-

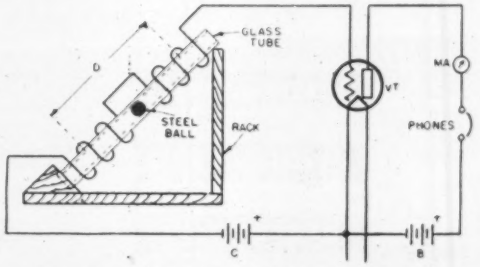

Fig. 198. A simple electron-tube viscosity meter.

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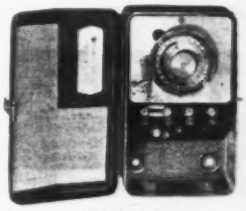

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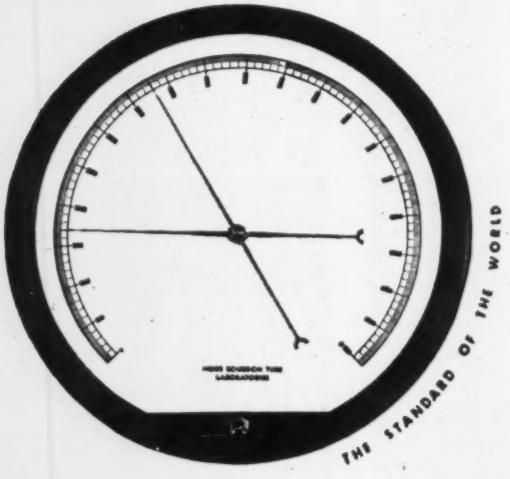

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ment and the sensitivity and speed of action of electron tubes enables them to meet almost any control problem that may arise. The application about to be described is one which involves a principle useful in solving many control problems and making use of the fact that the high-vacuum tube is essentially a high-impedance control device.

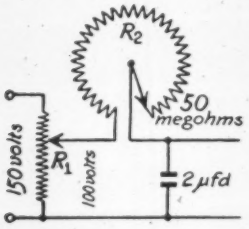

Fig. 199. Capacitor discharge circuit used to introduce time delay in electric circuits for certain control purposes. The rate of charge of the capacitor depends upon its capacitance and the resistance of R_2.

Consider the circuit shown in Fig. 199. This consists of a resistor and capacitor combination. A voltage source obtained across a voltage divider R_1 is used to charge a two-microfarad capacitor through a variable resistor set at its maximum value of 50 megoms. If the voltage across the divider is 100 volts, the voltage across the divider will become 63 volts at the end of 100 seconds after the charging begins. The rate of voltage increase is, of course, dependent upon the capacity of the condenser and the rate at which current flows into it; with a fixed capacity, the higher the resistance, the slower the rate of charging.

If the resistance in series with the condenser in Fig. 199 is reduced from 50 megohms to its minimum value of 0.1 megohm, the voltage across the condenser becomes 63 volts only 0.2 second after charging begins. Considering 63 volts as a control reference, any time delay from 0.2 second to nearly two minutes may be obtained simply by adjusting the resistor R_2.

The idea involved in this circuit is simple but it is not a simple matter to measure the voltage across the capacitor. The resistance of any voltmeter or other voltage-measuring device must be very high; if it is not, the capacitor will discharge through the resistor windings of the voltmeter faster than it can charge through the supply-side resistor.

The solution to this problem, as may have been suspected, lies in the electron-tube voltmeter. The input resistance of the electron tube voltmeter is extremely high and furthermore the circuit may contain relays for cutting in or out other circuits when the capacitor voltage has increased to the reference value.

This combination of a capacitor discharge circuit and an electronic tube provides the fundamental elements for indicating the rate of change and the direction of change of an electric potential and it has many applications, three of which are of direct importance in central station control problems, these are, the impulse relay, the electronic voltage regulator and the automatic synchronizer.*

Consider the circuit in Fig. 200 which is similar to the one in Fig. 199. The current through tube 3, for a definite plate voltage E_p depends upon the voltage E_g of the grid bias battery 4. If a voltage E_1 is applied with a polarity as shown, a charging current will flow through resistor 2 to the capacitor. This charging current will produce a voltage

*"The Principle of Condenser Discharge Applied to Central Station Control Problems." F. H. Gulliksen. *AIEE Proceedings*, Vol. 52, March 1933, page 232.

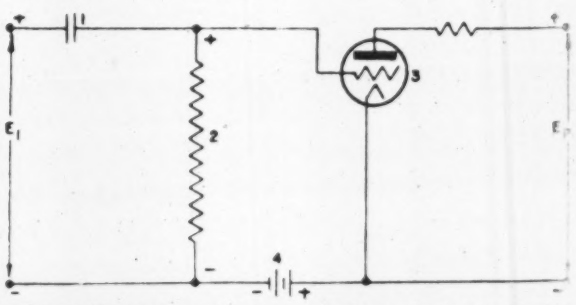

Fig. 200. The fundamental capacitor discharge circuit as used with a thermionic tube for measuring the rate of voltage change of E_1

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WEIGHT: 1½ POUNDS

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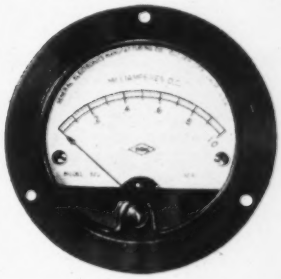
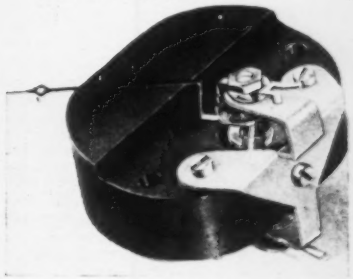
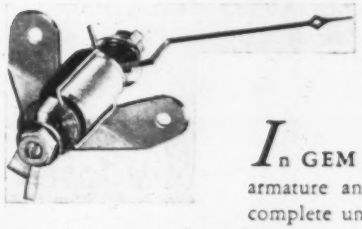


Face view of the GEM meter shows the linear scale which makes these instruments particularly adaptable to special jobs where multiple scales are needed. GEM meters measure current wherever current is to be measured.



Detailed view of the unit construction showing the ALNICO magnets that make this unit lighter and more compact. Notice how this completely modern design gives it a pleasingly smooth contour. By loosening the two screws shown, the movement unit may be lifted free.



The D'Arsonval type movement unit lifts out of the magnetic unit without disturbing the jewel bearings, armature or core, thus, realignment is unnecessary.

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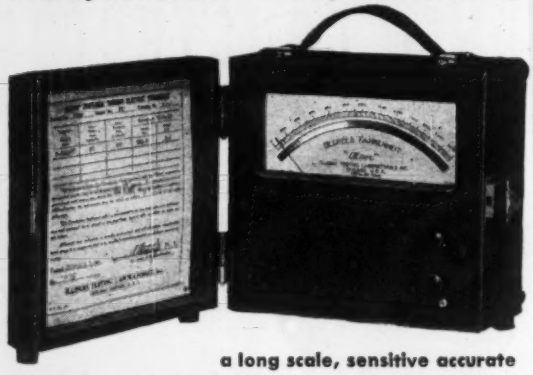

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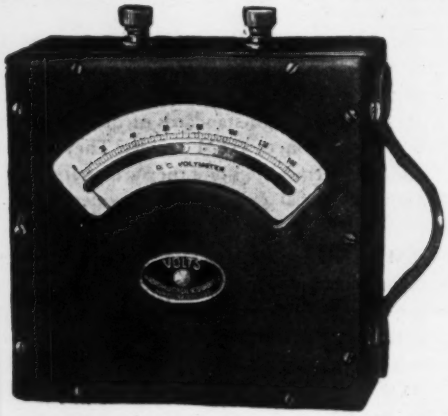

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drop across the resistor with a polarity as indicated. Consequently the bias on the grid of tube 3 will become more positive and the current through the tube will increase. After a definite time, dependent upon the time constant of the discharge circuit, the capacitor will be fully charged and the charging current, and consequently the voltage drop across the resistor, will become zero so that the current through tube 3 will come back to the original value as determined by the grid bias battery. If now voltage E_1 is varied, a voltage drop across the resistor takes place which is essentially proportional to the *rate of change* of E_1 and the polarity of this voltage drop will reverse if the direction of change of E_1 is reversed. The important feature of this circuit are that the output of the tube is not affected by the magnitude of voltage E_1 but only by the rate of change of E_1 and further, that since resistor 2 may be several megohms only a minute amount of control power is needed.

Impulse Relay

A scheme for an impulse relay for quick-response excitation voltage regulators, using this capacitor discharge principle, is shown in Fig. 201. With this type of equipment it is highly desirable to provide additional field forcing by shunting out all resistance in series with the exciter field if a sudden drop in regulated voltage should occur.

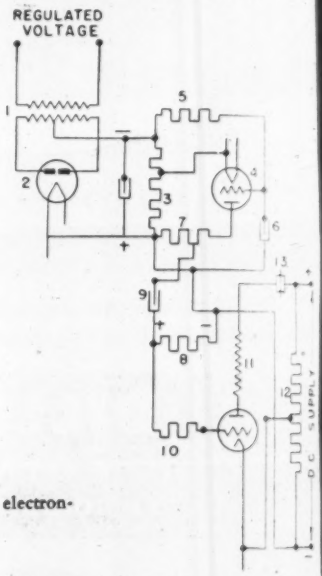

Fig. 201. Circuit diagram of the electron-tube impulse relay.

A transformer 1 is connected to the regulated voltage source and feeds into the full-wave rectifier tube 2. The direct-current voltage across resistor 3 will, therefore, be proportional to the regulated voltage. An amplifier tube 4 is connected to resistor 3 in such a manner that the plate current of tube 4 does not change if the regulated voltage changes slowly. This condition is obtained by selecting the location of the resistor tap so any change in tube plate voltage is compensated for by a proportional change in grid bias voltage. A resistor 5 and a capacitor 6 are connected in a discharge circuit to the grid of tube 4 so that for decreasing regulated voltage the grid of tube 4 will become more negative and consequently the voltage drop across resistor 7 will decrease due to the decreased plate current of tube 4. When the voltage drop across resistor 7 decreases, a voltage drop will appear across resistor 8 due to the discharging action of capacitor 9. The polarity of the voltage drop across resistor 8 will be as indicated in the diagram, so that the grid voltage of the glow tube 10 becomes more positive and causes tube 10 to break down and energize the quick-response shunting contactor coil 11. Contactor 11 remains closed until the direct-current supply voltage for tube 10 is disconnected by means of the contacts 13 of the field-current-limiting relay. The d-c. supply for tube 10 is supplied from the 250-volt station bus through the voltage divider.

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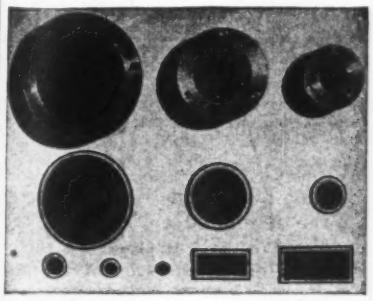

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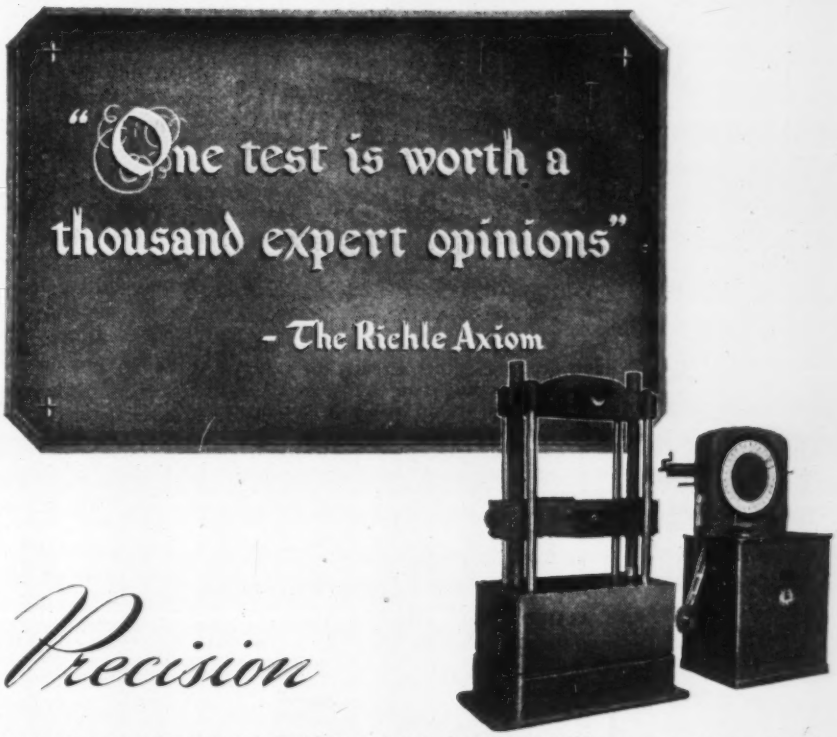

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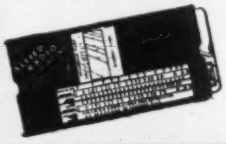

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tric and Mfg. Co. the response of this equipment compares favorably with the electromechanical quick-response voltage regulators at their best and the response does not depend upon the voltage conditions immediately before the fault occurred as is the case with the electromechanical regulators.

Voltage Regulation

Since the capacitor discharge circuit is so sensitive to voltage changes, it is obvious that this principle is well adapted to voltage regulation and this is the case; it is an important feature of several electronic voltage regulators which have been placed on the market. Such regulators are now available for d-c. and a-c. generator voltage regulation. The important features of these electronic type regulators are the high sensitivity, the simplicity of operation and the extremely fast response characteristic. This fast response characteristic is made possible through the application of the capacitor discharge as an anti-hunting means.

Because of the inductive lag of the field windings of exciters and generators, the generator armature always lags in relation to the exciter field current, if the exciter field current undergoes a change as a result of regulator action. If no anti-hunting action is provided, the generator armature voltage will not have reached the normal value when the exciter field attains the value corresponding to the new generator load conditions. As a consequence, when the generator voltage is brought back to the normal value, the

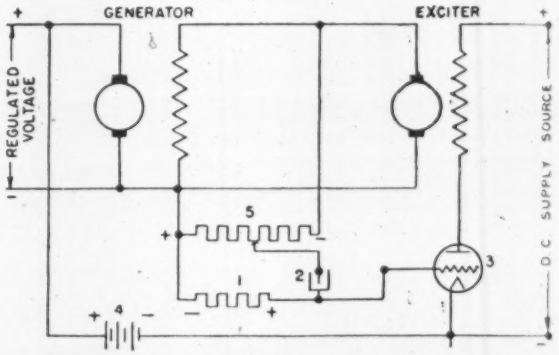

Fig. 202. Schematic diagram of an electronic voltage regulator using the capacitor discharge principle.

exciter field current will be too high if the regulator action was caused by a drop in the regulated voltage and, even though the regulator immediately starts to decrease the exciter field current, the generator armature voltage continues to increase for a definite time dependent upon the lag characteristic of the machine combination. Naturally, such a system will be unstable unless a zone is introduced within the limits of which the voltage being regulated can vary without bringing into play the field current correcting forces.

In the electron tube regulator for d-c. generators described by F. H. Gulliksen, the exciter field winding is connected in series with a 3-electrode tube as shown in Fig. 202, the plate voltage of which is supplied by a separate d-c. source. The generator voltage is opposed by means of a battery so that the increasing generator voltage will increase the negative bias on the grid of the tube and thus, decrease the exciter field current.

The anti-hunting is obtained through the capacitor discharge circuit consisting of resistor 1 and capacitor 2 which is connected in series across the exciter armature. When the exciter armature voltage is decreasing the polarity of the voltage drop across resistor 1 will be as shown in the diagram and will, therefore, provide a positive bias on the tube. This positive bias counteracts the original negative bias resulting from the initial increase in regulated voltage and consequently tends to stabilize the equipment.

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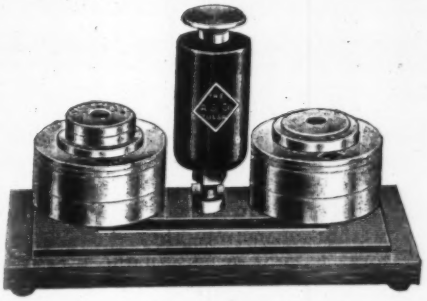

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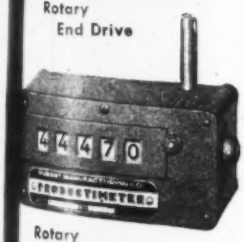

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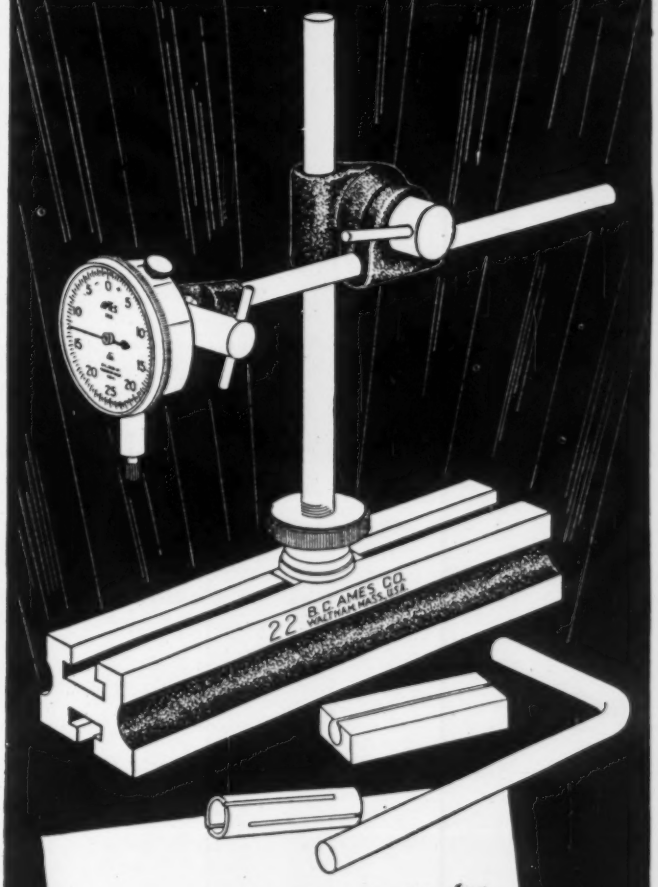

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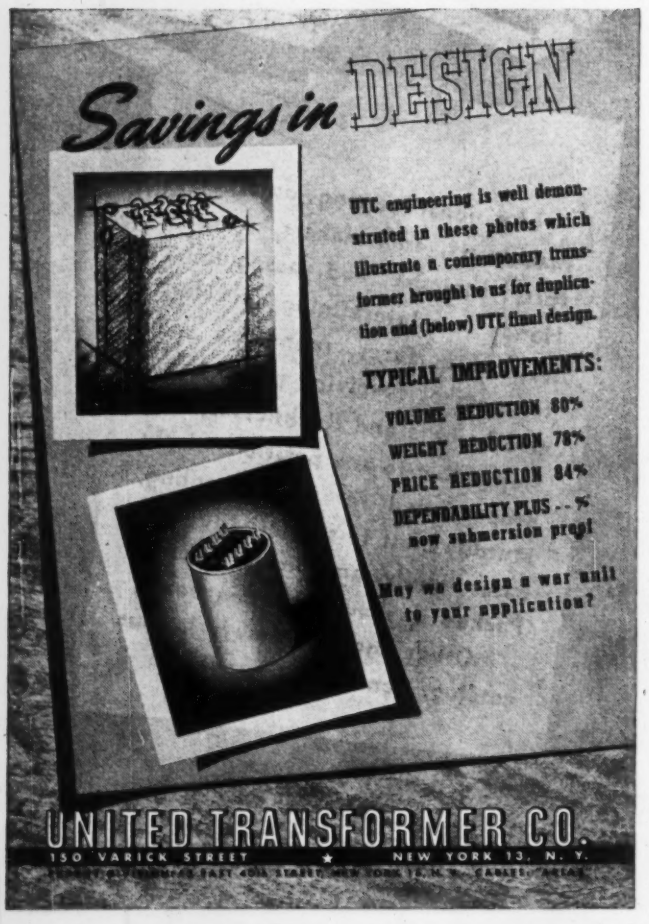
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pacitor discharge circuit, it should be noted that the amount of anti-hunting force is proportional to the *rate of change* of exciter armature voltage and that consequently the anti-hunting force is zero until the exciter armature voltage starts to change. The anti-hunting action does not tend to decrease the initial response of the field current change. The anti-hunting action is controlled by means of a small radio type voltage divider shown in Fig. 202.

This type of voltage regulator using the capacitor discharge principle is one of a number of different types of voltage regulators using electron tubes which have been developed. While these regulators have by no means supplanted the electromechanical type for large capacities their use for small units is increasing and there is no reason to believe that ultimately they will not be used for large generators. As will be shown in subsequent articles electronic devices are capable not only of acting as voltage regulators but can also furnish the field current for the generator; in other words, it is possible to have an electron tube exciter. Whether such electronic exciters possess advantages over present equipment sufficient to displace the latter remains to be seen.

Automatic Synchronizer

The same capacitor discharge principle used in the impulse relay and the voltage regulator just described has also been applied in an automatic synchronizer. This is a

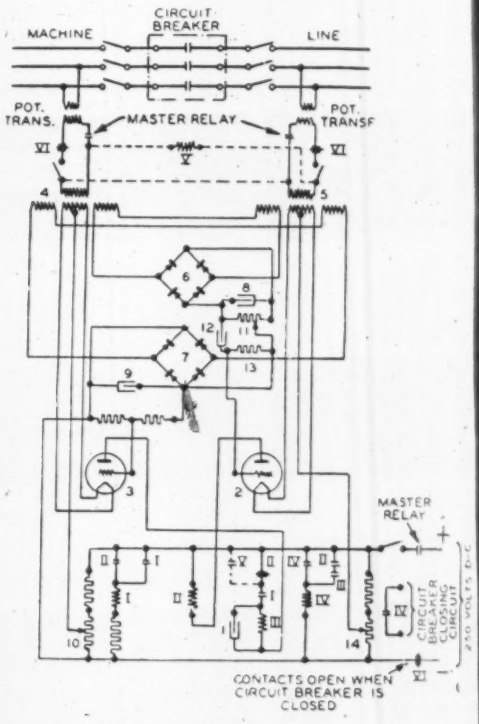

Fig. 203. The electron-tube automatic synchronizer.

more complicated circuit than either the impulse relay or the voltage regulator and while a complete description will not be presented here, a few comments regarding the circuit shown in Fig. 203 will make clear its essential features.

It involves the use of two thermionic tubes, 2 and 3, controlling two relays II and III. These relays are of the telephone variety and so arranged that relay III operates at a fixed point in advance of synchronism, the closing characteristic being independent of the frequency difference. Relay II which is called the advance relay on the other hand is so arranged as to operate at a point in advance of synchronism proportional to the frequency difference. An interlock is provided between these two relays so that third relay (IV) which is the energizing relay closing the main circuit breaker, is closed only if relay III is closed before relay II closes.

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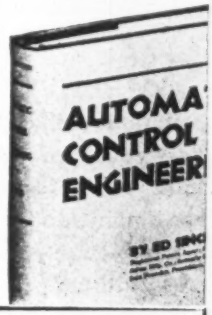

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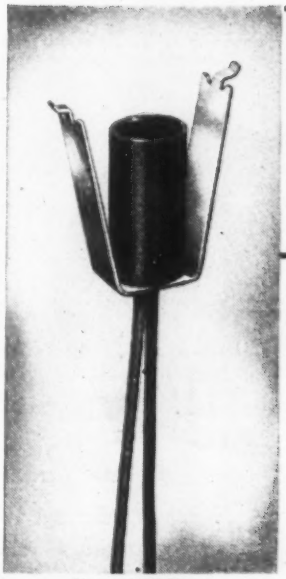

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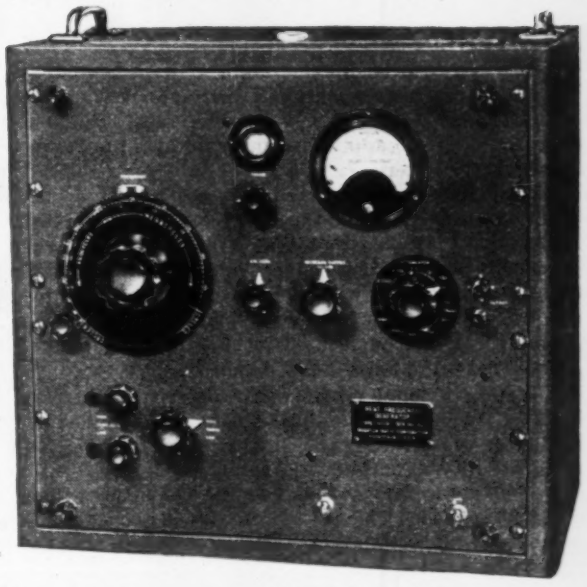

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of relay III across a 250-volt d-c. supply circuit. The grid bias for this tube is supplied from the rectified beat voltage obtained from the copper oxide rectifier 7. When the phase angle between the system voltage is 180° a high negative bias is, therefore, applied to the grid and the tube current consequently is zero.

As the phase angle is reduced, the negative bias is decreased and the current through relay III is increased. The system is so arranged that at a definite phase angle displacement between the system voltages the current through the coil of relay III will be high enough to operate the relay. By adjusting the voltage divider 10 the operating point of relay III can be located at any position between zero degree and 40° phase angle displacement.

The proportional advance characteristic of relay II is obtained by the action of the capacitor discharge circuit consisting of capacitor 12, resistor 13 and copper oxide rectifier 6. The d-c. output voltage of the rectifier will be pulsating at a rate proportional to the frequency difference of the two systems. The voltage across capacitor 12 is equal to the output voltage of rectifier 6 when the frequency difference is zero.

When there is a definite frequency difference between the two systems and the phase angle in changing from 180° toward zero, then the voltage across the terminals of the rectifier and the voltage across capacitor 12 will be higher than the rectifier voltage by an amount dependent upon the time constant of the discharge circuit and the frequency difference. The discharge current from the capacitor will produce a voltage drop across resistor 13 so that the potential on the grid of tube 2 becomes less negative. When the phase angle displacement between the system voltage is increasing from zero to 180° the polarity of the voltage drop across the resistor is reversed. Considering the performance of the automatic synchronizer the conditions for decreasing phase angle displacement only are of interest since no relay action can take place when the phase angle displacement is increasing.

Thus, in these three applications of the capacitor discharge principle, we see that all three are dependent upon the use of electron tubes. These three cases are presented here because they display the voltage measuring capabilities of the electron tube in three important control devices used in the electric generating plant. None of the devices considered has any moving parts outside of the relay contacts and all of them have definite advantages over similar forms of control using electromechanical principles.

Use Amplifiers Only Where Needed

The foregoing applications of amplifiers are only a few of hundreds of uses for them in the field of instrumentation but they are representative and other uses will suggest themselves. They should be used only where needed, however. When sufficient power is available to operate standard electromagnetic instruments, there is no particular advantage in substituting electronic measuring devices for our standard electromagnetic instruments, since these are simple, accurate and reasonably priced. But for purposes where these standard measuring instruments do not apply, the electronic methods offer new and far reaching opportunities. As Dr. Hull of the General Electric Co. has put it, "electronic devices enable us to measure, without disturbing them, smaller voltages, smaller currents, smaller distances, smaller times, smaller sounds and smaller light. Examples of smaller voltages include the transient voltage due to heartbeat and nerve action; of small currents, the ionization due to a single photon; of small distance, the separation of atoms in a molecule; of small time, the breakdown of a spark in air or vacuum; of small sounds, speech transients and the noise of machines; of small light, the radiation from a distant star."

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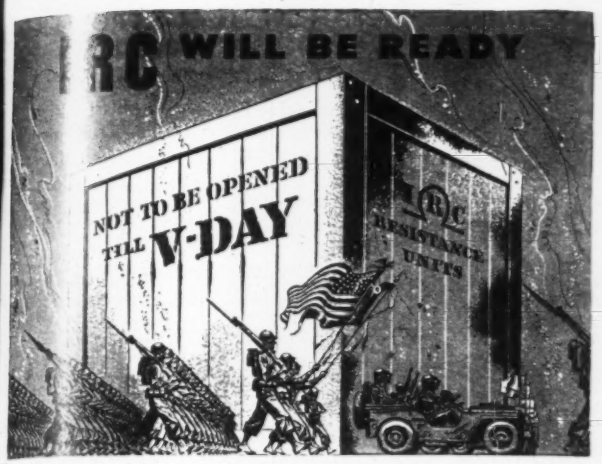

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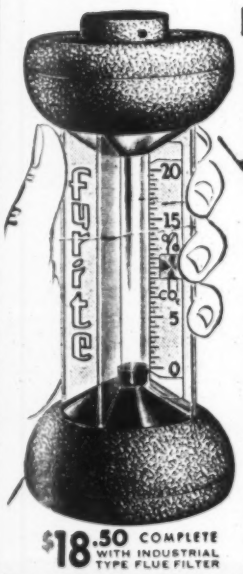

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19 October 1944

Mr. J. S. Eagen, President
Simpson Optical Manufacturing Co.,
3200 West Carroll Ave.,
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Dear Mr. Eagen:

Due to the untiring efforts of the men and women of the Simpson Optical Manufacturing Company to produce the equipment needed for victory, the Navy Board for Production Awards at its last meeting granted your plant a fourth renewal of the Army-Navy "E" Award. A new flag with four stars will reach you in the near future.

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In view of your excellent record, the Army and Navy have decided that your company may retain the flag for a year before being considered for the next renewal. It is our sincere hope and desire that you will keep up the good work and that your present record will be maintained or exceeded in the future.

Sincerely yours,
C. C. Bloch
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Chairman, Navy Board for Production Awards

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FAN-SPEED CONTROLLER ADJUSTMENTS

Continued from page 667

"following" fan controller. (See Fig. 2.) This piston-and-cylinder arrangement serves the purpose of readjusting the "proportional band" of the "following"

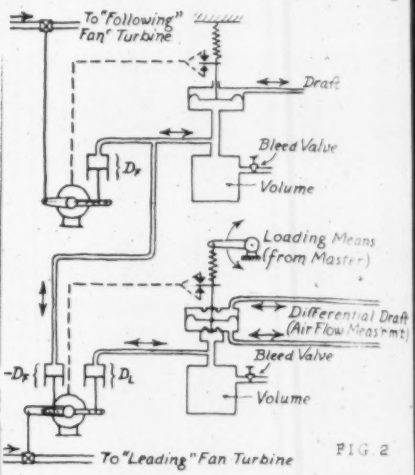


FIG. 2

fan controller; and it allows the "following" fan to follow closely the accelerations and decelerations of the "leading fan."

It has been found, however, that the piston-and-cylinder on the "leading" fan controller power unit should have only about 75% of the displacement of the piston-and-cylinder of the "following" fan controller drive unit in order to keep the "following" fan from actually *leading* the "leading fan" during a change. This adjustment is accomplished by crank radius decrease.

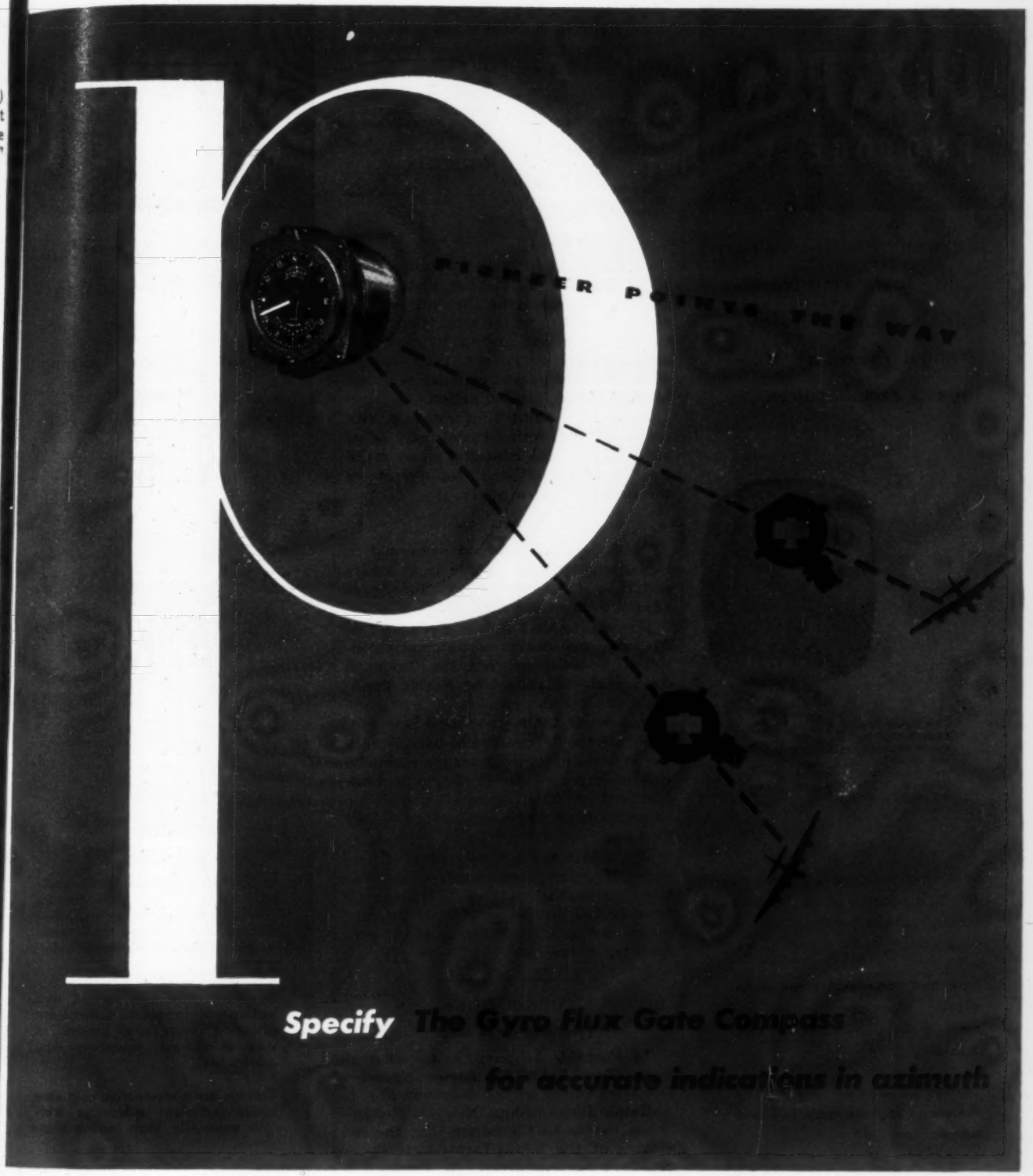
This system also helps preclude the possibility of the fan controllers getting too far out of phase and hunting between themselves.

V. Special Cases

When the pump type of hydraulic coupling is used as a fan drive, there is no reference movement that will signal the controller how much change it has made other than the quantity of oil which has been pumped in or out of the coupling; and the measurement of oil level either in the coupling or reservoir might be termed difficult or impractical to serve as such a reference. Coupling power transmission increases with an increase of oil quantity in the coupling and as the coupling power transmission increases, the fan speeds up.

Since the oil pumps are of the positive-displacement type and their motors constant-speed, the time and direction the pump runs will serve as a measurement of the change in oil level in the coupling and its power transmission change.

Therefore, if a small motor-driven positive-displacement air pump is substituted for the piston-and-cylinder and connected into the control circuit so that it runs in the same direction and the same length of time that the oil



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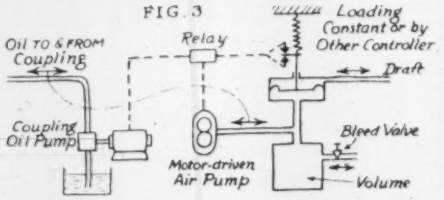
pump serving the coupling does, the same controller action takes place and the fan speed is controlled as previously described. (See Fig. 3.)

FIG. 3



Of course, this small air pump may be substituted for the piston-and-cylinder for supplying the "proportional bands" in any of the controllers mentioned above but, owing to cost and complication, it is not used except where the piston-and-cylinder will not accomplish the desired action.

A case in point is a rotating kiln where the connecting tubing may be of such length and capacity as to make the "proportional band" too narrow or the installation too costly.

VI. Conclusion

We hope that the data presented in this discussion will be of help to others and that it will help make for closer adjustments in the field.

We realize that it is a discussion of how only one design of automatic controller is adjusted, but the "common denominators" should be closely applicable to other designs.

In general, the method used is to precalibrate the "proportional band," making it wide enough to assure stability, and making a relatively simple field adjustment of "floating rate" and minor adjustment of "proportional band" by field test.

These data are a cross section of perhaps fifty fan speed control applications on boilers ranging in capacity from 35,000 lbs./hr. to 250,000 lbs./hr., some having economizers and/or preheaters, others not.

CORRECTIONS

(October 1944 issue)

"A Portable All-purpose A-c. Instrument Test Set." By James Spencer. Omission in the wiring diagram, Fig. 2. —Ralph Blankenship, New Castle, Indiana, wrote to the editor that the resistors of the power-factor-meter portion are not connected. He enclosed a new diagram. We consulted author Spencer, who explained that only two short lines had not been inked in. Readers can complete the diagram by drawing these two $\frac{1}{8}$" lines from the "50" and "100" points to the adjoining conductors.

Editorial on "Fuel Saving Starts With Control."—J. H. Burton of the National Fuel Efficiency Section, Bureau of Mines, points out an error in the last sentence of my editorial: "Regional Engineer" should be substituted for "Waste Chaser" because a "Waste Chaser" is on the staff of one company, while a "Regional Engineer" covers many plants.

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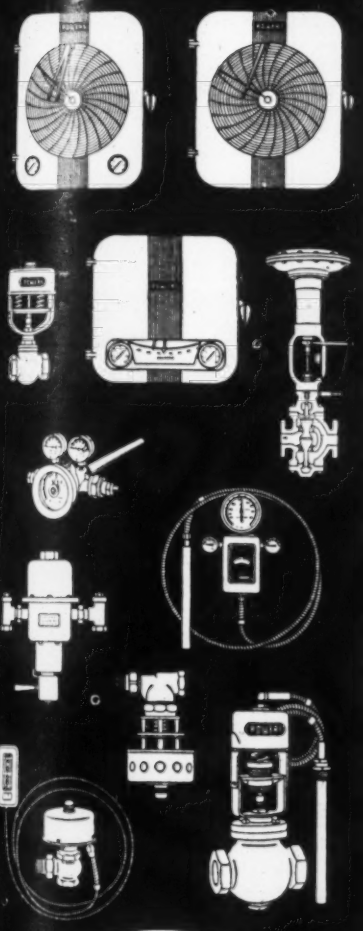

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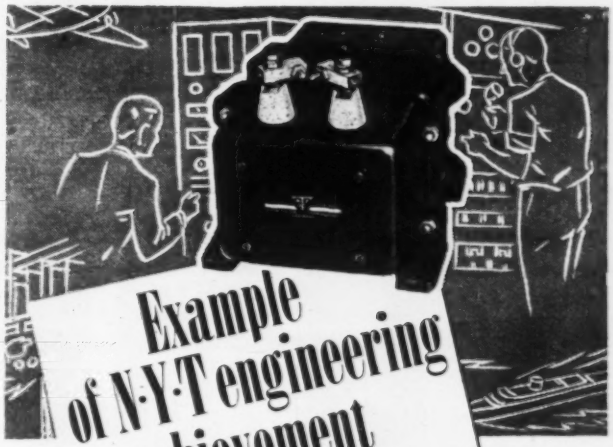

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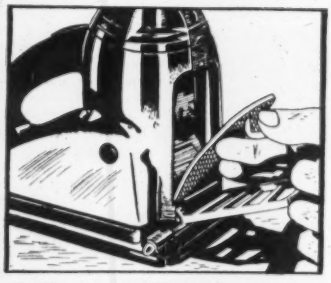
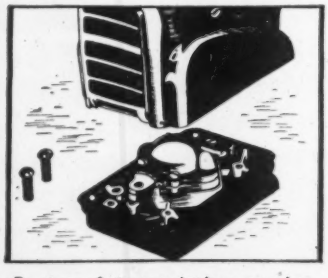


Easily-removed filter cleans air that cools motor—prolongs motor life and reduces maintenance costs.



Dustproof transmission synchronized to eliminate vibration. Oil supply lubricates for 100 operating hours.

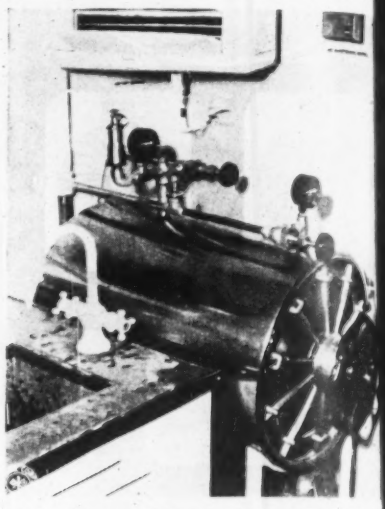
Y-160

MOBILE FOOD LAB

Continued from page 664

cans contaminated with certain other types of spoilage.

The first tour of the mobile laboratory was made through Illinois and Wisconsin at the peak of the pea-canning season. Some fifty canning plants were examined and their facilities checked. The touring-laboratory project was undertaken by the Quartermaster Corps with coöperation of the National Canners Association. The fifty plants visited produced approximately 4,379,354 dozens of cans of peas for Army procurement and, of this total, according to the official report of the tour, correction of production conditions with regard to "flat sour" contamination was made in the case of approximately 347,930 dozen cans. A total of 588,930 dozen cans were found to contain potential "flat sour" thermophiles and, as such, were reported as being undesirable for shipment to hot climates.



Showing the autoclave, one of the important items of equipment of the Quartermaster Corps Mobile Chemical & Bacteriological Laboratory.

During the entire tour, the personnel of the mobile laboratory enjoyed full coöperation of the canners visited in the interest of improving the quality of their products from the standpoint of bacteriological and chemical purity.

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The Month's NEW INSTRUMENTS

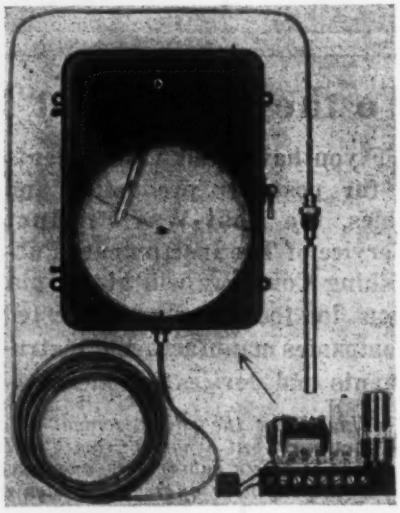
In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department. Or write to Information Section, Instruments Publishing Company.

On-off-time-ratio-adjusting Type of Temperature Controller for Electric-heat Input

New "Micromax Electric Control, Duration-adjusting Type" is said to bring to electrically-heated furnaces, ovens, and similar units as dependable a regulation of temperature as position-adjusting type of maker's Micromax electric control has brought to fuel-fired furnaces. New system not only regulates electric input to hold temperature at a selected control point or to a program, but is said to hold it there so dependably that most efficient balance among product uniformity, speed of output, flexibility of operation is achieved. By means of an "on-off" contacting system, new system feeds to heating unit the electric current needed to keep temperature to required control point or program. Input is either "full-on" or "full-off." Regulation is obtained by controlling automatically the time during which current is "on" and "off." Employing balance method both for measurement and control, new system is a complete coördinated one. It provides "full proportional time action," as compared with the more familiar "full proportional positioning action." It provides automatic droop-correction. It can be equipped with Overshoot Control, valuable when the furnace or other unit is coming up to temperature.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

Inductance-coupling Type Automatic Controllers

New Free-Vane "Electronic" Controller is said to operate on "the shielding effect" of a vane passing between two coils in an "electronic" circuit. Recording and indicating models are offered for automatic control of temperature, pressure, liquid level, and humidity. The following modes of control are available: low-open, high-open, low-high, low-open-high, and low-normal-high. Temperature controller is available in ranges from —125°F. to 1000°F. for use in conjunction with motor and solenoid valves, relays, main line switches, etc. Pressure controller is available in ranges from full vacuum to 6000 lbs./in.² and also liquid level control. Humidity controller operates from a wet- and dry-bulb type of element with separate control for each bulb. New controller is also offered as a time-program controller for automatically controlling temperature, pressure, liquid level or humidity according to a definite time schedule.—*The Bristol Co., Waterbury 91, Conn.*

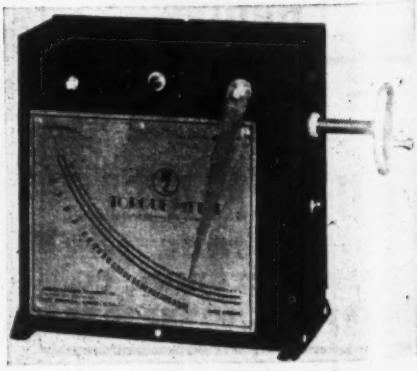


Industrial X-ray Unit

New "Norelco Searchray 150" is a complete self-contained industrial x-ray unit which provides a quick, accurate means for non-destructive examination of specimens for internal flaws, cracks or foreign matter. New "Searchray" is said to be inexpensive to install and easy to operate. Kilovoltage dial has scales calibrated for various thicknesses of aluminum, steel and brass, so that even an inexperienced operator can quickly learn how to operate effectively. Other features are the oil-immersed water-cooled tube; rayproof and shockproof safety features; fluoroscope for visual inspection and cassette for film exposures; storage cabinet for exposed and unexposed negatives; pushbutton control; smooth, stepless kilovoltage adjustment; electric timer having a range from 1 to 20 minutes with 10-second intervals; and the variable filament control with a range from 5 to 10 milliamperes.—*North American Philips Co., Inc., 100 E. 42nd St., New York 17, N. Y.*

Torque Meter

New "B/L Torque Meter" has been specially developed for testing and accurately setting torque tools such as torque wrenches, torque screwdrivers, etc. Its normal range is 0 to 750 in.-lbs. and dial calibration is in 1-in.-lb. increments. Special adapters (other than standard accessories) permit measurements to 7500 in.-lbs. Standard accessories are ¼", ⅜" and ½" square-drive socket adapters. Operation is simple: turn adjusting handle until pointer indicates desired torque; put wrench on adapter and when



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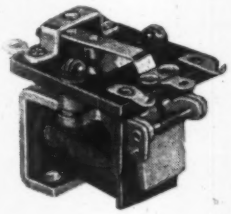

...perates on d.c. only, and has a switch ca...acity of double-pole double-throw with ...5-amp. contacts. Power requirement, 1.75 ...watts.—*Guardian Electric Mfg. Co., Dept. M-R, 1638 West Walnut St., Chicago 12, Ill.*

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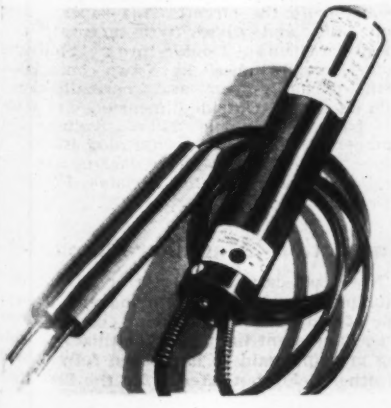
...years. It tells at a glance the "inside ...tory" about liquid level content of drums ...ontaining oil, solvents, etc.; eliminates tap...ping, measuring, guessing. New model fits ...all 55-gal. and 30-gal. drums; as easy to transfer as a faucet—merely screw into drum faucet opening; then screw faucet in...to opening on indicator body. When drum ...is empty, merely remove entire assembly ...and attach to a full drum.—*Techtmann Industries, Inc., 828 North Broadway, Milwaukee, Wis.*

Voltage Testers

New "SDP-2 Knopp Voltage Testers" are handy instruments for measuring circuit voltages and for determining whether they carry a.c., pure d.c. or rectifier d.c. They operate on the solenoid principle, and indicate the nominal a-c. circuit voltages of 110, 220, 330, 440, and 550, and the nominal d-c. circuit voltages of 115, 230, and 600. A neon-light polarity indicator in the "SDP-2" is a new exclusive feature which not only shows the polarity of a d-c. circuit under test, but which also enables one to differentiate readily between a.c. and rectifier d.c. current as well as between a.c. and



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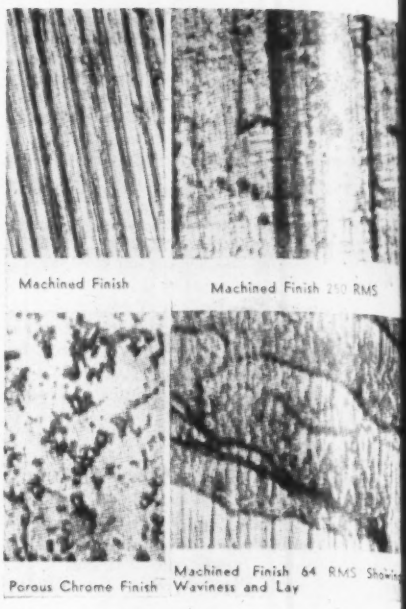
pure d.c. In addition, this light signals the presence of potential in daylight or darkness and provides together with the solenoid indicator a dual means of detecting voltage. Thus the neon indicator and the solenoid, connected in parallel, offer excellent protection against the danger which exists when an ordinary test lamp burns out, the danger of having no indication of voltage when voltage is actually present. Among other innovations, Knopp Testers contain a mounting in the top of the case into which one prod may be inserted so that only the tester and one prod need be handled during tests. Incoming leads are physically separated from each other within the case for added safety in testing heavy-power circuits. A junior model, the "SDP Tester," is also being offered, which does not have the neon polarity feature, but which is otherwise identical with the "SDP-2."—*Electrical Facilities, Inc., 4250 Holden St., Oakland 8, Calif.*

Replica Films for Inspection of Surfaces

New "Faxfilm" is a clear plastic which reproduces non-photographically characteristics of a surface on which it is pressed, then can be used in any type of projector so that details of surface irregularities as small as 0.0001" can be viewed conveniently. "Faxfilm Kit" comprises a roll of plastic film, a bottle of solvent, 250 cardboard frames, a moistener and an instruction folder. The film itself, when dry, has a relatively hard surface so that ordinary handling does not produce fingerprints that would spoil replica of surface being studied. However, when one side of the film is moistened by the solvent as per directions, this side becomes soft enough to fill every depression when the film is pressed on the surface to be studied. (Surface of subject is likewise moistened by means of the same solvent just before applying "Faxfilm.") After 30 to 60 seconds, the piece of film is peeled from the subject, mounted and sealed in a frame, and becomes a permanent record.—*Rex D. McDill, 5109 Mayfield Rd., Cleveland 21, Ohio.*



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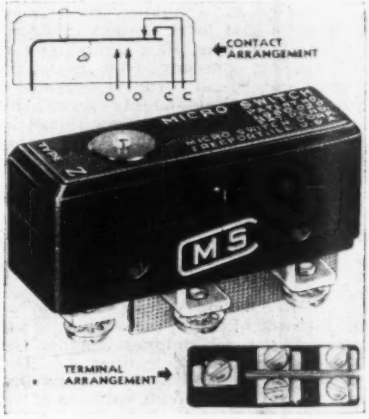
IN PRODUCTION and IN RESEARCH, wherever complicated physical or chemical processes are involved, Weksler precision instruments are definitely needed!
Dial Indicating types have easy-to-read 4½", 6" or 8½" dial, in latest phenol condensate case, and are mercury, vapor or gas actuated.
Recording types have 10" or 12" chart, and are mercury or vapor actuated.
Industrial types have "V" shape bronze case, removable glass front, red reading or yellow back mercury tube, and with any desired stem.
Glass Precision Thermometers, Hydrometers, Psychrometers and Hygrometers are made in various scales and ranges, for many definite duties.
Send for interesting new folder No. G 20.
Weksler Thermometer Corp.
52-56 W. Houston Street
New York 12, N. Y.

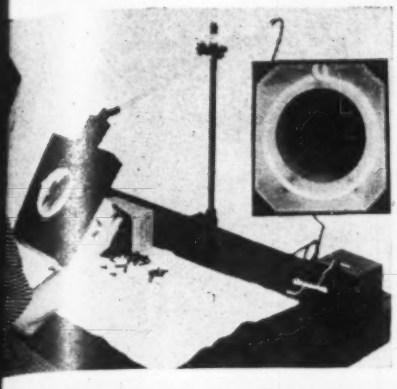
Split-contact Micro Switches

New "Split-contact Micro Switches" are said to simplify many otherwise-complex electric circuits. By use of double-throw "Split-contact Micro Switch" it is possible, for instance, to switch operation from a d-c control to an a-c. control. Two sets of contacts are mechanically interlinked but electrically isolated. Micro Switch transfer action is a matter of but a few milliseconds. It is possible also with this switch to control four isolated circuits by pairs, eliminating use of relays and other isolating means from the circuit. This saves weight and bulk and gives more accurate and speedy response. Double-throw "Split-contact Micro Switches" have two contacts on both normally-open and normally-closed side as shown. Outside dimensions are same as basic single-pole Micro Switch. Pin plunger design shown is "Catalog BZ-3YT." Type "D" and "S" plunger designs are also available.—*Micro Switch Division, Freeport, Illinois.*



Inspection Magnifier-illuminator

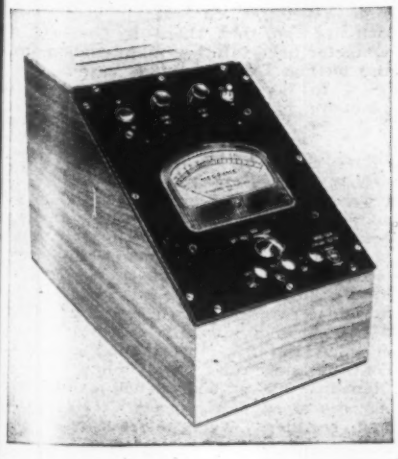
New cold-cathode no-starter "Inspector" equipment is distinct from maker's present line of "Inspector" equipment (usual starter type fluorescent lighting). It utilizes a lighting principle said to have been fully proved in other fields but offered for the first time

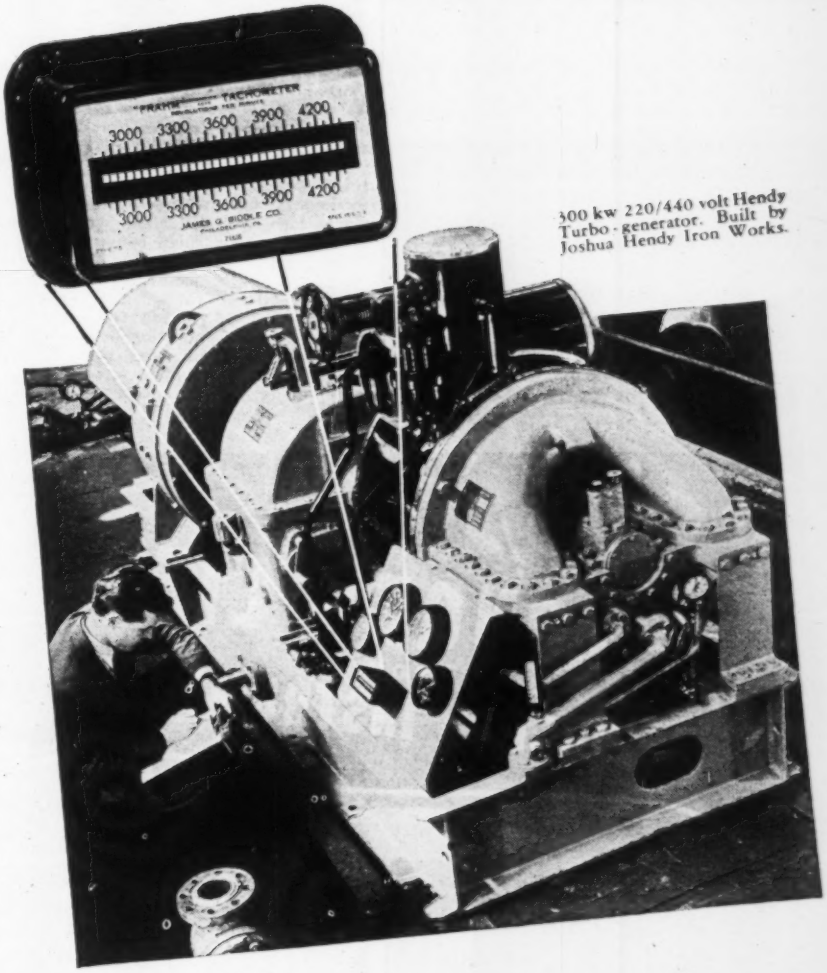


by anyone for inspection use. It is entirely of maker's own design (including the fluorescent tubing) and is said to have "startling advantages for many applications" based on following characteristics: Advantages: (1) No starter, ON and OFF like an ordinary incandescent; (2) fluorescent tubing of circular form entirely around the 5" magnifying lens (but shielded from the lens)—result, soft, clear daylight with no shadows whatsoever; (3) life of fluorescent tubes estimated at 10,000 hours; (4) operates on 115-volt 60-cy. a-c. which is converted by a small transformer 2,000-volt 15-ma. secondary, adequately installed for safe operation; (5) transformer is in a separate housing which can be fastened up near the plug-in. Disadvantages: (a) ON and OFF switch cannot be placed in the head but must be in the transformer box near the plug-in, but a pull cord is provided; (b) replacement cost of tubes, and time required to make change, greater than with ordinary fluorescent, but long life of tubes and shadow-free characteristic of the light offset this slight disadvantage; (c) new units are available in clamp or screw-on type table models in maroon for shop or inspection use, not available in double-lens types (such as maker's No. 1234-W55) nor for installation over grinding wheels or such other locations.—*The Larrimore Sales Co., P. O. Box 1234, St. Louis 1, Mo.*

High-resistance and Capacitor-leakage Tester

New "Model L-2 Megohm Meter" incorporates a vacuum-tube voltmeter in order to cover relatively high resistance values, and is said to incorporate several features new for this type of instrument. In addition to laboratory use (checking leakage resistance, etc.) it is readily adaptable to production testing, particularly of radio capacitors. It is self-contained and operates on 110-volt 60-cycle a.c. Arrangements are provided for rapid charging of capacitors under test. An external battery voltage supply may be used where voltage other than the self-contained 200-volt sup-





300 kw 220/440 volt Hendy Turbo-generator. Built by Joshua Hendy Iron Works.

. . . making **"ASSURANCE DOUBLY SURE"**

***with the* "FRAHM" RESONANT-REED TACHOMETER**

In the modern turbo-generator, uniformity of speed must be maintained over the entire range of no-load to overload conditions.

The Hendy unit shown above has a carefully designed and precisely built governor to assure uniform speed under widely varying load conditions. As a double check, however, Frahm Resonant Reed Tachometers are used on Hendy and other well-known turbo-generators, both large and small, to provide the operator with constant proof of turbine speed. Manufacturers select Frahm instruments for this service because of their simplicity of construction, ease of installation and freedom from maintenance.

Frahm Tachometers are built in both stationary and portable types for use on many kinds of machines having rotating parts. Various ranges are available from 900 to 60,000 r.p.m.

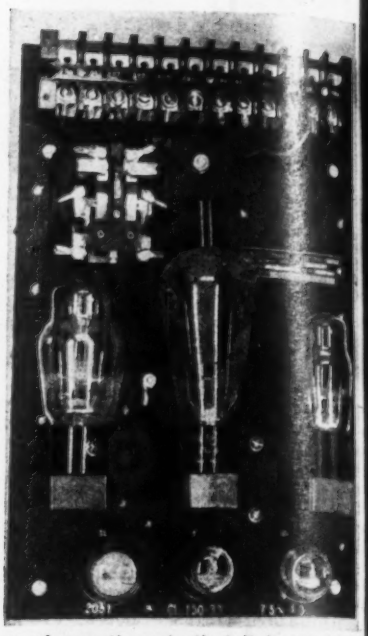
For a complete description of Frahm Tachometers together with list of types and ranges commonly supplied, write for Bulletin 1590-I. The instrument shown above is listed in Bulletin 1740-I.

JAMES G. BIDDLE CO. 1211-13 ARCH ST. PHILADELPHIA 7, PA.

ply are desired. Instrument may be satisfactorily operated with voltages up to 1000. Internal resistance standards enable operator to check calibration and make compensating adjustments when necessary. Scale length is 4¾" with "less crowding at high-resistance end than is usual in such an instrument." Using external 200-volt supply maximum range goes up to 100,000 ohms, but can be extended to 500,000 megohms with an external 1000-volt supply. Maximum resistance in series with capacitor or insulation under test is 1 megohm, assuring practically constant voltage across test terminals and minimizing effect of tube ground current. Stability is said to be assured by balanced tube circuit and voltage regulators in internal power supply. Dimensions 10" h. × 8" w. × 15" deep. Weight 10 lbs.—*Industrial Instruments, Inc., 17 Pollock Ave., Jersey City, N. J.*

Timer for Capacitor-discharge Resistance-welding Control

New precise forge-pressure timer, incorporated in capacitor-discharge controls for use with stored-energy type resistance welding machines, is designed for dual pressure spot welding machines of the capacitor discharge type, functions to supply accurately-timed forge-pressure so that required welding energy, cracks, indentations, and sheet separation are reduced. Calibrated in milliseconds, new timer consists of a timing circuit with a regulated d-c. source of voltage to assure accurate timing; the necessary electronic tubes; and a time-delay relay with fixed timing for compensating for the delay in operation of solenoid valve on welding machine, so that the forge-pressure can be applied precisely at any point during the current discharge. A feature of new timer is that it is mounted on a small steel base so constructed that it can be added to any G-E capacitor-discharge control already installed, provided that the resistance welding machine has a dual pressure system designed for this purpose.—*Industrial Control Division, General Electric Co., Schenectady, N. Y.*



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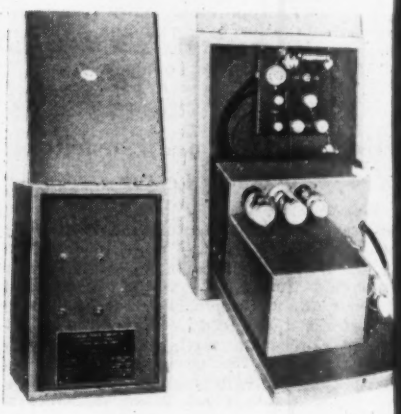
Resistance-welding Timer

New "electronic" timing control for a resistance-welding operations is said to step up product quality and uniformity; assure rapid, consistent welds, even with an inexperienced operator. It is said to be easily



applied to either existing or new installations. A single knob gives instant time control from 1 to 28 cycles in steps of one cycle. Welding current is electronically switched, so that there is freedom from contactor uncertainties, maintenance, arcing and pitting. Device handles welding powers of ½ to 5kva.—*Electrical Industries, Inc., 42 Summer Ave., Newark 4, N. J.*

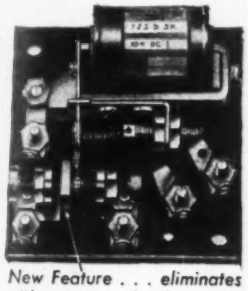
Tube Tester

New "Model 314 Tube Tester" is said to be exceptionally flexible, is said to offer simplicity and speed of operation in testing octal, loctal, bantam Jr., miniature, midget and all acorn tubes. Filament voltage switch is designed to test all present filament voltages from 1.1 to 117 volts—a range said to anticipate voltages of near future. "Model 314" has individual connections for each element. Lever type switching individually controls each tube prong, checks roaming filaments, dual cathode structures and multi-purpose tubes. Separate plate tests on diodes and rectifiers. Neon short tests indicate

htest leakage between any two elements
le tube is hot. 4½" rectangular indica-
has "Poor-Good" scale. "Pilot Lite" in-
ator for "on-off." A double fused plug
tects the transformer. Oak carrying case
h handle for portable or counter use.
e: 14¼" × 13" × 6"; 12¼ lbs.—*Radio*
y Products Co., 127 West 26th St., New
k 1, N. Y.

Flat Keying Relay

New "Chatterless 200S" flat keying relay
the "Kurman Old Timer" relay ("200"
les) with an improvement which consists
an energy-absorbing material, sealed



New Feature . . . eliminates "bounce" and "chatter"

thin a contact-carrying cage. The com-
und used is not affected by age, oil or
isture. Characteristics: Input 50 milli-
atts. Will key up to 150 words minute,
60 impulses per second. Armature is
ca-insulated; is suitable for keying a 50
egacycle r.f. signal. Contacts will carry
to 2 amps.—*Kurman Electric Co., 35-18*
th St., Long Island City, N. Y.

Armature Tester

New Ainor Armature Tester is designed
r rapid production testing of small arma-
res up to 125 volts, provides quick, posi-
ve tests of armature coils, solder joints,
d commutator bars. Ohmmeter indication
ill reveal a short-circuited armature coil,
ovide a check on the proper number of
rns per coil, will also reveal a short cir-
uit between adjacent commutator bars.
igh-voltage impulse test applies a mo-
entary high voltage to adjacent commu-
tor bars, and an indicator lamp flash re-
eals short circuits between commutator
rs. Blowout action of high-voltage im-

Meet "Old Faithful"

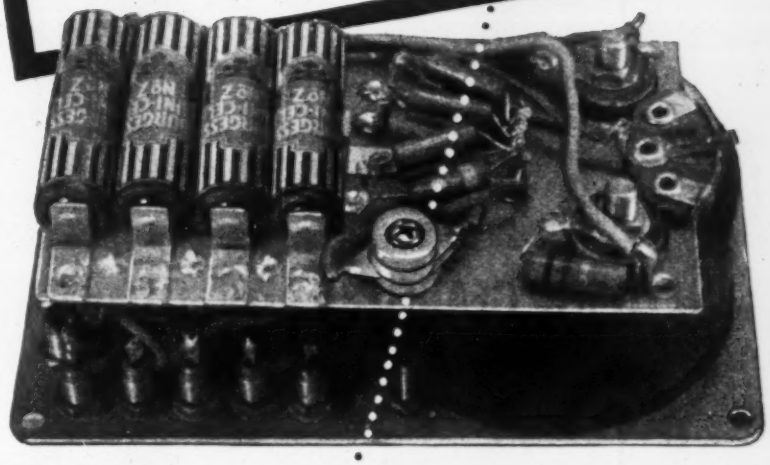


Photo Courtesy
Supreme Instruments Corp.
Greenwood, Miss.

Conant's SERIES 500

Series 500 (.500" diameter discs) is the general service unit of the Conant family of instrument rectifiers. Its design and construction are the result of more than eleven years of constant experience and close co-operation with instrument manufacturers.

Here is a rectifier that will take accidental overloads in its stride without damage because of its rugged construction and ample disc area.

Assembly operations are simple and speedy with its single mounting stud. For all general applications at commercial and lower audio frequencies, you'll be wise to choose Conant's "Old Faithful," Series 500.

Instrument Rectifiers

CONANT ELECTRICAL LABORATORIES

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85 E. Gay St., Columbus, Ohio
600 S. Michigan Ave., Chicago 5, Ill.
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7935 Eustis St., Dallas 18, Texas
4018 Greer Ave., St. Louis, Mo.
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4214 Country Club Dr., Long Beach 7, Cal.
4205 N.E. 22nd Ave., Portland 11, Ore.
Caixa Postal 930, Sao Paulo, Brazil
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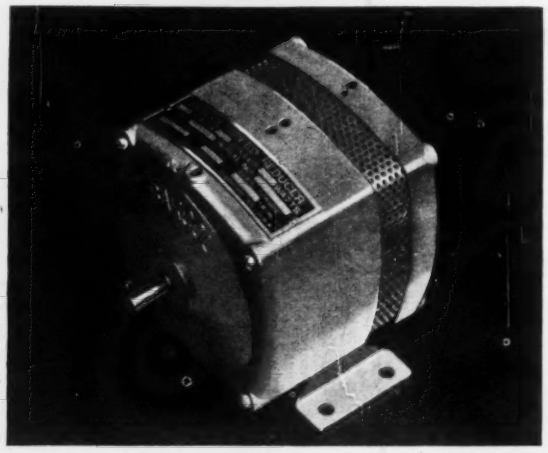

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ENCLOSED GEARED-HEAD MOTORS

350 r.p.m. to 1 revolution in 7 hours

Since their introduction 6 years ago, these motors have proved extremely satisfactory in service and have been applied successfully to such exacting jobs as driving telescopes, radio beam directors, voltage controllers, and similar applications. Practically any gear ratio from 7.2/1 up to 1,098,632/1 can be furnished. Available with either shaded-pole induction or synchronous motor. Shaft is centrally located. Accurate, durable construction throughout.

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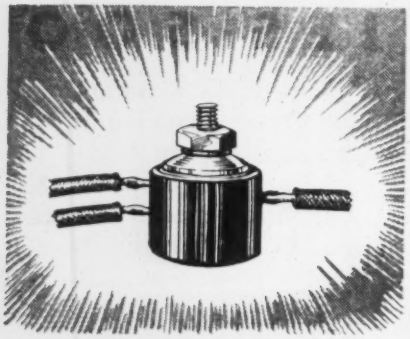


ELECTROX RECTIFIERS

• All kinds of rectifiers for all purposes . . . any capacity. Suppliers of Electrox Rectifiers to leading instrument and test-set makers since 1930.

Write for illustrated Bulletin 446.

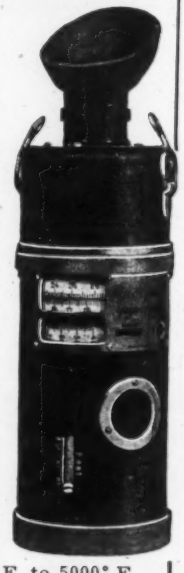
SCHAUER MACHINE COMPANY
2055 READING RD., CINCINNATI 2, OHIO

PYRO THE SIMPLIFIED OPTICAL PYROMETER

SAVE TIME AND MONEY!

By using PYRO, a self-contained, DIRECT READING, sturdy unit made to stand rough use. It is absolutely accurate and dependable, and quickly pays for itself.

Unique construction enables operator to rapidly determine temperature even on minute spots, fast moving objects, or smallest stream; no correction charts, no accessories, no maintenance expense. Special "FOUNDRY TYPE" and "Universal TRIPLE RANGE" have, in addition to standard calibrated range, a red correction scale determining TRUE SPOUT and POURING TEMPERATURES of molten iron and steel when measured in the open.



Stock ranges 1400° F. to 5000° F.

Write for Catalog No. 80

Immediate Delivery for Defense Plants

THE PYROMETER INSTRUMENT CO.
Plant & Lab
103-107 LAFAYETTE ST., NEW YORK, N. Y.
In Canada, Sales and Repair Laboratory:
Dominion Flow Meter Company Limited
Toronto and Montreal

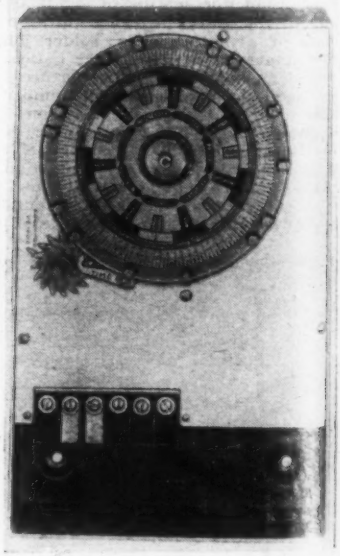
pulse test will remove metal dirt or bon which would cause a temporary between bars. A faulty solder joint cause an audible spark at the commutator bar, showing up a poor solder joint not sufficiently defective to affect the ohmmeter reading. Alnor Armature Tester is designed for operation on 110-120-volt, 60-cycle A fixture is required to suit the particular armatures being tested, built to provide brush contacts for the commutator bars to allow rotation for testing successive commutator bars and coils. — *Illinois Testing Laboratories, Inc., 420 N. La Salle St., Chicago 10, Illinois.*

Air-operated Indicating Controllers

New "Model 93 series" indicating operated controllers are available in models for controlling temperature, pressure, vacuum, liquid level, and humidity. They operate on "Free-Vane" principle (*see Instruments*, Oct. 1938, pages 232-233; Nov. 1938, pages 336-337). They have a throttling range of ½ to 15% with the adjusting mechanism arranged so that changes in throttling range can be made by user without tools. They can be changed by a fine adjustment from reverse-action to direct action or vice versa. — *The Bristol Co., Waterbury 91, Conn.*

"Calendar-type" Time Switch

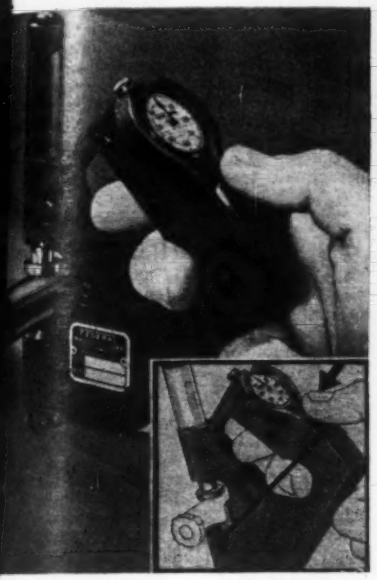
New "700 Series" 7-day calendar, dial time switch is said to have demonstrated its worth for timing automatic heat, ventilating, lighting, pumping or flushing operations. Calendar dial is 6" in diam, and makes one revolution every 7 days. Dial trippers can be independently set for different daily ON and OFF schedules. Setting can be made in advance for an entire week. Any day or days operations may be omitted entirely on a pre-set program. Each



of week clearly separated from other ; graduated into hours and half hours; and night distinctly separated. Operation from OFF to ON or from OFF to ON can set as close as three hours apart and be separately adjusted throughout each four day in the week.—*Paragon Electric 55 West Van Buren St., Chicago 5, Ill.*

Indicator Snap-gage with Retractable Anvil

New "Model 1330 P-100 Visual Dial Indicator Snap-gage" obviates need of feeling and thereby eliminates personal element in gaging. In addition, it is provided with a retractable anvil to prevent marring high-finished components. It is easily adjusted



any dimension within one inch and locked in place. In normal use, weight of gage and inspector's hand rests upon the fixed or reference contact. Gage weighs 15 oz. and reads in 0.0001".—*Federal Products Corp., 44 Eddy St., Providence 1, R. I.*

Miniature Six-element Oscillograph

New "Type PM-17-A1" self-contained permanent-magnet oscillograph (the world's smallest six-element unit) consists of three principal systems: (1) optical system; (2) six parallel galvanometer channels; (3) photographic-material-transporting mechanism with internal motor and removable film holder—all enclosed within a light-weight metal case 4½" × 4½" × 14". Weight of complete instrument is approx. 7 lbs. Said to represent a big advance in the oscillograph art, new instrument makes

Model 645 A.C.-D.C. Electronic Multimeter

(Vacuum Tube Voltmeter)

Both A.C. and D.C. volt ranges are electronic. This provides the maximum of sensitivity and overload protection for all A.C. ranges as well as D.C. and ohms ranges.

Measures resistance up to one thousand megohms and as low as 2/10 ohm.

Constant input resistance 12 megohms on all D.C. volts ranges.

Input resistance 4.4 megohms on all A.C. ranges. Flat frequency response between 50 cycles and 10,000 cycles.

Meter cannot be damaged by accidental overload on any electronic range. Electronic overload protection on all A.C. and D.C. volts, and ohms ranges.

Variations in line voltage do not affect accuracy within the range of 100 to 125 volts. The instrument is equipped with ballast control tube and self-compensating circuits.

Meter Ranges—

A.C. Volts: 0-1/4/10/40/100/400/1000

D.C. Volts: 0-4/10/40/100/400/1000

Ohms: 0-1000/10,000/100,000/1 meg/10 meg/100 meg/1000 meg

M.A.: 0-1/4/10/40/100/400/1000

Decibels: Minus 30 to minus 5/minus 10 to plus 15/10 to 35/30 to 35

Either positive or negative D.C. voltmeter indications instantly by means of reversal switch. Signal tracing type test lead with isolation resistor in probe. Model 645 is an ultra-modern high sensitivity instrument, with all of the famous Jackson features, including exceptional accuracy and simplicity of use.

MODEL 645 **Net Price** **$56.50**

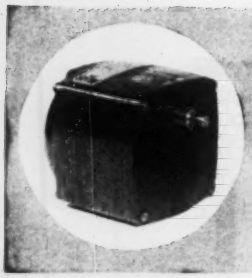
Available *now* on *rated orders* . . . after war a new regular in the Jackson line . . . a line that shall always live up to a long reputation for **INTEGRITY OF DESIGN.**

BUY WAR BONDS AND STAMPS TODAY

JACKSON

Fine Electrical Testing Instruments

JACKSON ELECTRICAL INSTRUMENT COMPANY, DAYTON, OHIO



PRECISION MOTORS
for important instrument applications

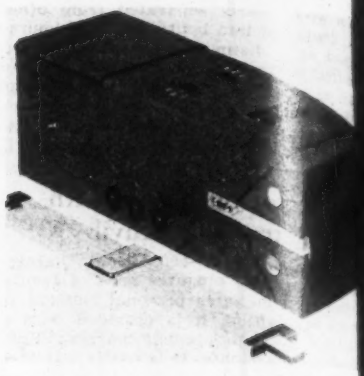
Bodine Type K Motors are small, rugged, and extremely dependable for instrument and precision devices requiring small power, accurate speed and repair-free service. Available in synchronous and non-synchronous types with or without speed reduction gears.

TYPICAL APPLICATION
Bodine Type K Synchronout Spur Gear Speed Reduction Motor used in Crouse-Hinds Traffic Signal Timers.

The selection of a drive for a motor driven instrument requires careful consideration. Correct type and size of motor are important—but equally important is the name of the motor manufacturer because it is the best guarantee of dependable performance and long, trouble-free life.

Many makers of precision instruments put their trust in Bodine motors . . . because Bodine has been a leading manufacturer of fractional horsepower motors for over 35 years, and because instrument makers know that Bodine Engineer's wide experience in motor application eliminates guesswork and assures the correct selection from the start. Bodine Electric Company, 2244 W. Ohio St., Chicago 12, Ill.

BODINE FRACTIONAL HORSEPOWER MOTORS



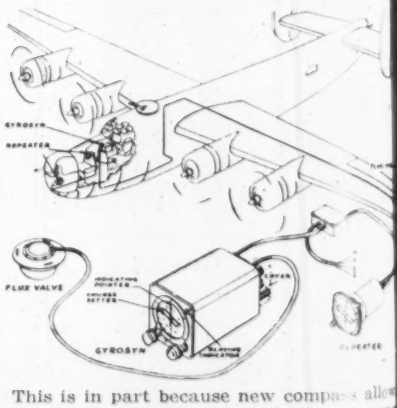
it possible to obtain performance records aircraft and also on industrial equipm where space and weight limitations clude use of the larger general-purpose t It is designed to directly record "s values" of potential or current, such as put of amplifying equipment. A wide ra of potentials or currents can be recor by the use of appropriate external resist instrument transformers, or shunts.—*eral Electric Co., Schenectady 5, N. Y.*

Fuse Panels

Blueprints for new "No. 1505 Univer Fuse Panel" are available on request manufacturers making or using electri equipment, engineers, draftsmen, prime c tractors, and purchasing agents. Espec advantages are said to be found in th use in airplanes. They can be placed at accessible point, rather than in a cent junction box. Industrial laboratories or sh benches can use them for holding bars various diameters. They also serve as te porary switches. Circuit can be opened pulling out a metal bar from the clips, w insulated pliers. Thus an ammeter can inserted at this point for a temporary re ing. Panel "No. 1505" is for Littelfuse A G and 3 A B, 4 A G and 4 A B, and 5 A and 5 A B Aircorps Type of fuses and cli One number covers mounting. User n only take blueprint and in a few momen check all factors for panels to his specifi tions: First dash number indicates fuse s cification; second dash number specifi number of poles. Specifications include b bars if required, and number of poles to bussed.—*Littelfuse, Inc., 4757 Ravenswo Ave., Chicago 40, Illinois.*

Airplane Compass with Repeate

New "Gyrosyn Compass" combines fu tions of a directional gyro and a magnet compass and result is said to make not on for greater accuracy in navigation but al greatly to lighten and simplify pilot's duti



This is in part because new compass allow for deadbeat indication and accurate mag netic headings without northerly turnin error or the necessity of resetting an avoids effect of disturbances in the earth magnetic field due to proximity of electric apparatus and armor plate. "Gyrosyn Com pass" is an electrically-driven directiona gyro precisely controlled by a "Flux Valve

MOISTURE CONTENT
of lumber checked in
THREE SECONDS

At the press of a button, Moisture Register detects and measures moisture by the use of electronics.

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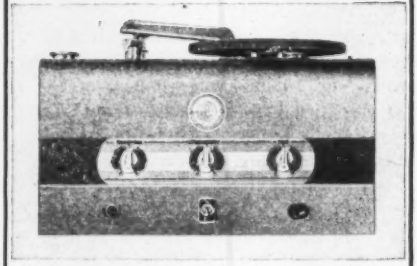

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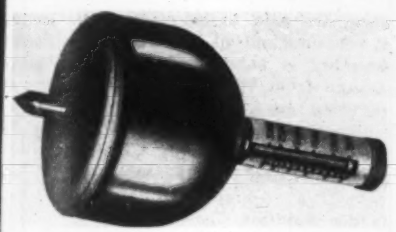
which de... its direction of the earth's magnetic field. "Flux Valve" is small, hermetically sealed and with no rotating parts, may be readily mounted in a wing tip safe... from disturbing influences of cockpit. "Gyrosyn Compass" is installed on pilot's instrument panel or at navigator's station. Up to six repeaters for remote indications may be used. "Gyrosyn Compass" with two repeaters weighs less than 12 lbs. Provision is also made for furnishing azimuth stabilization as required by any other equipment. When rough air momentarily swings "Flux Valve" out of horizontal, resultant fluctuating signals do not register as error on the Gyrosyn indicator because directional gyro effectively integrates all short-period disturbances and oscillations. In a prolonged turn, erroneous signals may show in part on the indicator but they disappear without oscillation and without any corrective measures on the part of the pilot as soon as plane has been returned to straight flight.—*The Sperry Corp., 30 Rockefeller Plaza, New York 20, N. Y.*

Hand Tachometer

New form of tachometer is said to differ "from everything on the market" in that it weighs 5½ ounces and is of 2¼" diam. permitting one-hand manipulation. Speed in r.p.m. is directly indicated, without timing or counting device. Readings are said to be



"constant and record fluctuations which are impossible with tachometers now on the market." Scale is black figures against orange background. Range is 500 to 3000 r.p.m. and it is said that "checks of stock models show a variation of less than 3% from absolute accuracy over the whole range." An elastic tip is furnished that slips over pointed spindle for use on shaft ends that are not centered. Tachometer is dust- and moisture-proofed and has a baked enamel protective coating on all surfaces except the scale, which is enclosed in a plastic tube.—*The Standard Machinery Co., Providence 7, R. I.*

Gas Leak Detector

New gas leak detector for barrage balloons is described as follows: "Small, flat and circular, with a porous clay back through which escaping gas is absorbed to push against anylon diaphragm. A gage connected to the diaphragm registers the rate of gas escape as the device is moved by hand over the balloon surface."—*Johnson Service Co., Milwaukee, Wis.*

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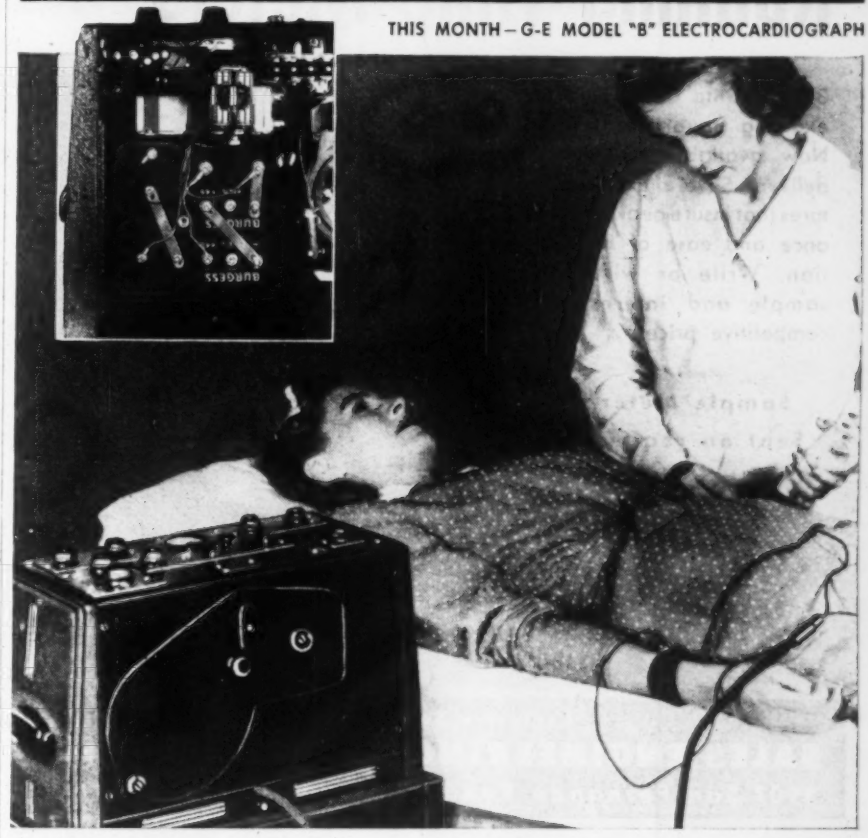
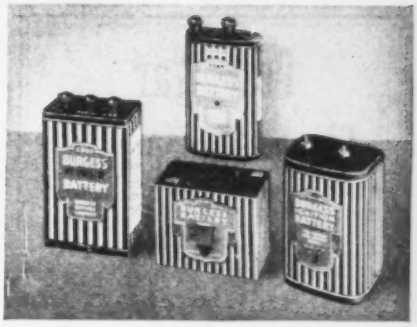
New "Type 581" supercharger regulators ("Model 12" for updraft carburetors and "Model 13" for downdraft carburetors) are designed to operate independently of carburetor throttle, automatically controlling the auxiliary stage of a two-stage engine supercharger system to produce constant carburetor air inlet pressure. Control of War Emergency Power is also incorporated. Carburetor inlet air pressure in a typical application is automatically held constant, at any altitude within rated limits of engine, by throttling inlet to auxiliary stage. Sensitive element, consisting of air pressure and evacuated bellows, measures carburetor inlet air pressure and functions continuously to prevent that pressure from dropping or exceeding the setting. Auxiliary stage inlet throttling valve is adjusted by an oil-actuated servo piston, commanded by the sensitive

PORTABLE POWER PROBLEMS

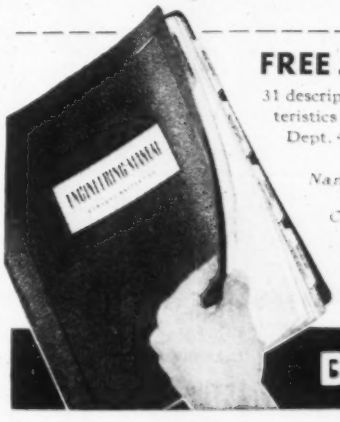
THIS MONTH—G-E MODEL "B" ELECTROCARDIOGRAPH



HIGH SENSITIVITY and standardized operation characterizes the General Electric Model "B" Electrocardiograph which assists doctors in quickly establishing accurate diagnosis and prognosis of heart conditions. A true photographic record of minute change in heart potential waves is given by this remarkable lightweight, *battery-powered* instrument. As a result, it quickly and economically makes available information that would otherwise be very difficult to obtain.



BATTERY COMPARTMENT, shown upper left, houses the power heart of the G-E Model "B" Electrocardiograph (Burgess "A" and "B" Batteries are standard equipment.) General Electric descriptive literature emphasizes that "batteries provide the most dependable source of power—always smooth." Battery power assures operation anywhere—independent of commercial electric supply. Burgess engineers are constantly adapting special-purpose batteries for specific commercial and industrial requirements. Let them solve *your* portable power problems. *Send coupon for free Engineering Manual.*



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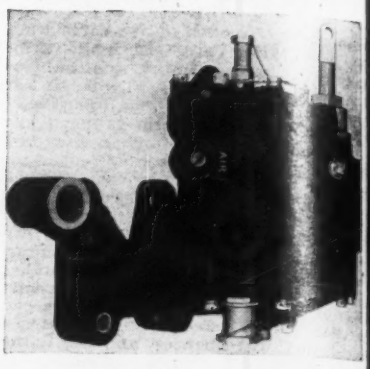

element through a valve. War Emergency Power is provided by a bellows which resets supercharger regulator, during water injection, to a higher value. Regulator is automatically reset to normal when supply of water is exhausted or when water injection is discontinued. Evacuated bellows provides a constant pressure control regardless of atmospheric pressure or temperature variations. Bellows assembly is of light weight to minimize acceleration loads. A balanced oil control valve is said to provide accurate regulation regardless of oil pressure variations. Low vulnerability and ease of installation are said to be provided by internal oil pressure and oil drain passages. Bellows assembly is submerged in oil, preventing damage from vibration and lubricating all operating mechanisms. New regulators are mounted on accessory drive section, are compact, and weigh only 4.75 lbs. Envelope dimensions are 7-13/16" wide × 6⅝" deep × 6-19/32" high.—*Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.*

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Statement of the Ownership, Management, Circulation, etc., Required by the Acts of Congress of August 24, 1912 and March 3, 1933, of *Instruments* published monthly at Pittsburgh, Pennsylvania, for October 1st, 1944.

State of Pennsylvania, County of Allegheny, (ss).

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Richard Rimbach, who, having been duly sworn according to law, deposes and says that he is the Publisher of *Instruments* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business manager are:

Publisher, Richard Rimbach, Pittsburgh, Pa.; Editor, M. F. Behar, Pittsburgh, Pa.; Managing Editor, Richard Rimbach, Pittsburgh, Pa.; Business Manager, Richard Rimbach, Pittsburgh, Pa.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock.)

Instruments Publishing Co., Inc., Pittsburgh, Pa.

M. F. Behar, Pittsburgh, Pa.; Jackson Burgess, Freeport, Illinois; R. K. Farnham, Newark, N. J.; M. D. Pugh, Altadena, Calif.; Martha B. Rimbach, Pittsburgh, Pa.; Richard Rimbach, Pittsburgh, Pa.; Freda Seibert, Pittsburgh, Pa.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholders or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

Richard Rimbach, Publisher

Sworn to and subscribed before me this 19th day of September 1944.

[SEAL] Louis D. Vogel

(My commission expires May 7, 1948.)

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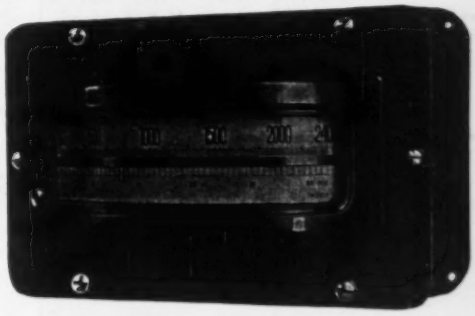

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INSTRUMENT SOCIETIES CALENDAR

City, Society and Secretary			Date	Place	Subject	Speaker
Atlanta	Georgia Society for Measurement & Control	Roger W. Allen, 376 Nelson St., S.W., Atlanta	Nov. 27(B)	Ellen Rice Tea Room	(To be announced)	
Baltimore	Baltimore Industrial Instrumentation Society	C. B. Willnecker, 6732 Danville Ave., Dundalk, Md.				
Chicago	Chicago Society for Measurement & Control	A. J. Butler, 2626 W. 31st Blvd., Chicago	Dec. 4(B)	Merchants' & Mfrs' Club, 237 M. Mart	Television & Other Future Aspects of Electronics	Commander W. C. Eddy, U. S. Navy
Cleveland	Cleveland Instrumentation Society	W. A. Stubblefield, 2085 W. 104th St., Cleveland 2	Nov. 22(B)	Cleveland Engineering Society	Industrial Electronics	T. A. Cohen, V.P. Eng'g & Research, Wheelco Instr. Co.
Fort Worth	Fort Worth Electronics Club	Ralph Ely, 1116 E. Arlington, Fort Worth, Tex.	Dec. 21(A)	Texas Hotel	Telemetering	H. R. McKenzie, Texas Electric Service Co.
Gulf Coast	Gulf Coast Instrument Maintenance Men's Ass'n	T. H. Pierson, 3030 Roberts St., Beaumont, Tex.				
Hartford	Hartford Society for Measurement & Control	S. J. Zelle, Bridgeport Thermostat Co., Inc., 1225 Connecticut Ave., Bridgeport, Conn.				
Kansas City	KC Industrial Instrumentation Society	Gordon H. Burke, 1527 Broadway, Kansas City, Mo.	Nov. 21(B)	Bluebird Cafeteria	Combustion Control Instrumentation of H.F. alkalation units	W. H. Pugsley, Hays Corp. C. E. Defabaugh, Phillips Petroleum Co.
			Dec. 19(B)	Bluebird Cafeteria		
Newark	New Jersey Society for Measurement & Control	Robt. H. Gray, 1 Whippoorwill Way, Mountainside, N. J.				
New York	New York Society for Measurement & Control	H. R. Kalbfleisch, 144-35 No. Blvd., Flushing, N. Y.	Dec. 26(B)	Men's Faculty Club Columbia Univ., 400 W. 117th St.	(To be announced)	Keith Henney, Editor of *Electronics*
N. Indiana	Northern Indiana Soc. Measurement & Control	R. W. Schreiner, 4 Waltham St. Calumet City, Illinois	Nov. 17(C)	Vogel Rest't, 1250 Indianapolis Blvd., Hammond, Ind.	Role of x-rays in testing and controlling industrial materials	George A. Russ
Philadelphia	Philadelphia Society for Instrumentation	J. E. Gambrill, 1317 Spruce St.	Nov. 15(B)	Engineers Club 1317 Spruce St.	Electronic Design Applied to Automatic Control	Dr. T. A. Cohen, Wheelco Instrument Co.
			Dec. 20(B)	Engineers Club 1317 Spruce St.	Manometer Applications in Industry	A. A. Hejduk, Meriam Instrument Co.
Pittsburgh	American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pgh.	Nov. 27(B)	Roosevelt Hotel	The WPB Instrument Jewel Program	C. Burgess, WPB, Washington
			Dec. 18(B)	Roosevelt Hotel	Dimensional Control as an Economic Force	I. A. Hunt, Federal Products Corp.
St. Louis	St. Louis Society for Instrumentation	Gus Holubeck, Union Electric Co., Venice, Ill.	Dec. 4(C)	Hotel DeSoto	Instr'n for variable-density Wind Tunnel	Loren Wood, Jr.
Toronto	Canadian Society for Measurement & Control	T. C. Agnew, Minneapolis-Honeywell Reg. Co., Toronto	Nov. 16(B)	(To be announced)	(To be announced)	Coleman Moore, President, Moore Products Co.
Washington, D. C.	Instruments Society of Washington	W. A. Wildhack, 328 N. Oxford St., Arlington, Va.	Nov. 21(D)	Interior Dep't Auditorium	Fractional-h-p. motors and instr. applic'ns	C. G. Veinott, Westinghouse E. & M. Co.
			Dec. 19(D)	do.	(To be announced)	
Wyandotte, Mich.	Instrument Society of Wayne County	John MacPherson, RFD No. 1, Wyandotte, Mich.	Nov. 27(B)	West Mound Church near Telegraph	Electronics	A. R. Satullo, Univ. of Detroit

(A)Meeting at 7:30, no dinner. (B)Dinner at 6:30, meeting at 8. (C)Dinner at 7, meeting at 8. (D)Meeting at 8, no dinner.

ATLANTA

At the Sept. 25 meeting of the Georgia Society for Measurement and Control we had two representatives of the Plantation Pipe Line Co. who gave us an illustrated informal lecture on the problems of pipelaying and the transportation of gasoline and oil. Everyone who attended was very much impressed with the subject and much constructive information was extended.

—ROGER W. ALLEN

On Oct. 23, at the last meeting of the 1943-44 season, the new officers were inducted: *Pres.:* M. Virgil Davis; *Vice-Pres.:* Don D. Beach; *Sec'y:* Robert E. Geminert (P.O. Box 1714, Atlanta); *Treas.:* Edwin R. Foss.

We heard a wonderful talk on aeronautics and the development of airplanes by Professor Allen Pope of the Aeronautical Experimental Station at the Georgia School of Technology.

As retiring President of the Society for the past year, I want to thank each and every one for his coöperation and help.

—HOWARD M. BARKER

CHICAGO

Our October meeting was well attended and we heard a very interesting talk on Rotameters by Kermit Fischer of Fischer and Porter Co. He began with a simple explanation of the operating principle with the help of sketches which he drew on the blackboard. This was followed by some interesting points in the early development of rotameters in France, England, and Germany. The importance of glass tubing manufacture with relation to accuracy was explained. Slides were used to show a large variety of rotameters and present-day applications.

The talk followed by a lively discussion in which Mr. Fischer answered a variety of questions. —GORDON THOMASON

KANSAS CITY

During the business session of our October 31 meeting H. B. Manley of J. F. Pritchard & Co. presented the list of nominees for officers for the coming year: for *Pres.*, Wm. A. Reichow (Minneapolis-Honeywell Regulator Co.) and R. B. Cook (Westinghouse E. & M. Co); *Vice-pres.*, Wm. G. Eargle (Phillips Petroleum Co.) and Harold Hoyt (Great Lakes Pipe Line Co.); *Sec-treas., Gordon H. Burke* (Burke Engineering Co.) and Lester Johnson (Sinclair Refining Co.). A motion was made by R. B. Cook and unanimously carried, that he be allowed to withdraw and Wm. A. Reichow remain president during 1945. Ballots are now being mailed to all members; closing time at next meeting on Nov. 21.

Donald R. Gifford (Alcoa) presented an enlightening basic lecture on thermocouple protecting tubes.

Our Quiz Kids, Joe Spacek (Alcoa), Larry Siler (Hercules Powder), Lester Johnson (Sinclair), and George Agin (Sheffield Steel), handled the hot ones like the veterans they are.

H. B. Manley (J. F. Pritchard & Co.) requests information that someone reading this may be able to furnish. Baker wishes to know if it is possible to obtain a table or chart showing the minimum length of thermocouple immersion to obtain accuracy in various media and varying temperature conditions.

Kermit Fischer, President of Fischer & Porter Co., presented an extremely interesting lecture on Rotameters. Present-day application and future possibilities were ably explained by Mr. Fischer. We can conscientiously report that everyone learned something new which will be of value to him in the future.

—GORDON H. BURKE

NEW YORK

At the October 31 meeting we had 62 for the dinner and 80 were present for the meeting. Dr. P. S. Christaldi of Allen B. Du Mont Laboratories spoke on "Laboratory and Industrial Applications of the Cathode-ray Equipment." He illustrated the use of the cathode-ray oscilloscope on various applications, and supplemented the lecture throughout with slides. Many questions were answered by Dr. Christaldi during the discussion period. —H. R. KALBFLEISCH

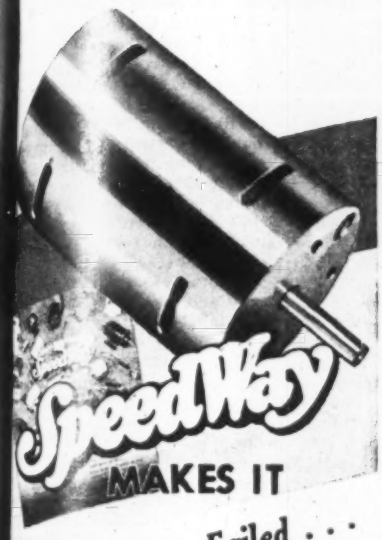
NORTHERN INDIANA

The September meeting of the Northern Indiana Society of Measurement and Control was held at Vogel Restaurant, Hammond, Indiana. The speaker of the evening was M. F. Behar, Editor of *Instruments*, and his subject was "Some Forgotten Fundamentals of Instrumentation." His explanation of fundamental characteristics of measuring instruments and automatic controllers was very educational. The meeting was attended by forty members and guests.

The October 20 meeting was held at the Lake Hotel in Gary, Indiana. The speaker of the evening was L. E. Eige, of Fisher Governor Co. and his subject was "Liquid Level Control." A number of diagrams were flashed on the screen as Mr. Eige talked, and they were explained and questions answered. Mr. Jimmy Riggs of General Meters & Controls Co. was master of ceremonies. Jimmy started the meeting off by telling a few of his many stories. The meeting was attended by thirty-five members and guests. —K. M. FRAMS

PHILADELPHIA

A very enthusiastic group at the October 18 meeting of the Philadelphia Society for



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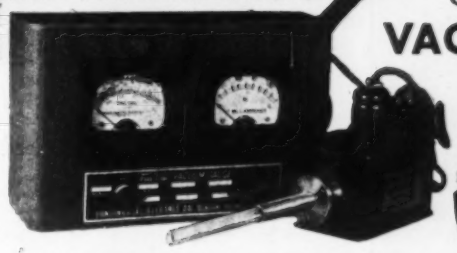

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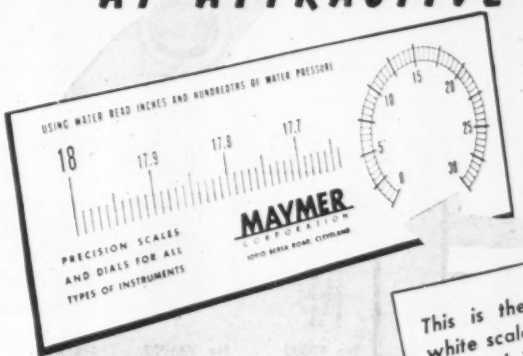

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Manufacturers of Temperature Instruments

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DETROIT 16, MICHIGAN

Instrumentation listened to a talk by M. Boho on "Combustion Control." Mr. B. pointed out that boiler control could be separated into the control of the following variables: (1) draft, (2) fuel supply, (3) fuel air ratio.

Mr. Boho outlined four fundamental systems of combustion control: (1) Independent control of fuel and air from the master sender; (2) Control of air from fuel input, which in turn is controlled by the master sender; (3) Control of the fuel from the air input, which in turn is controlled by the master sender; (4) Either No. 2 or No. 3 with interlocks to limit the control range of either variable.

Mr. Boho concluded with the description of a complete combustion control system for a boiler with a combination of blast furnace gas and powdered coal: particularly interesting because of complex problems.

The feasibility of a National Organization was discussed and we were privileged to hear Mr. Dewey of the Baltimore Industrial Instrument Society give us that society's reaction: he is the Chairman of the Committee to consider all such proposals.

The dinner was attended by an enthusiastic group of 59, and the meeting was attended by 101. The Secretary reported that we had 102 paid-up members for 1944 and 8 paid-up members for 1945.

—J. E. GAMBLE

PITTSBURGH

At the second meeting of the American Society for Measurement and Control for the 1944-45 season, there were fifty-eight present for the dinner and over one hundred at the technical meeting.

L. K. Spink of the Foxboro Company spoke on "Flow Measurement Engineering." He discussed the basic characteristics and principles of operation of the different type flow meter and conditions affecting their operation. Slides were used to illustrate a number of typical flow problems and possible errors in primary elements.

As an added feature, through the courtesy of The Brown Instrument Company two reels of sound motion pictures on the electronic automatic pilot were shown.

Art Schafer, Chairman of the Committee on Organization of a National Society which was appointed on June 26, 1944, submitted the Committee's first report. He announced that a Conference and Exhibit will be held at the William Penn Hotel during the week of September 17, 1945.

There having been no elections since June 9, 1941, a motion was made that the present Council be continued for the term 1944-45. It was carried unanimously.

—L. M. SUSAL

WASHINGTON

At the October 17 meeting of the Instrument Society of Washington, Dr. W. D. Rayton, Director of the Scientific Bureau of the Bausch and Lomb Optical Company gave an illustrated talk on "New Optical Tools for Research." A short motion picture entitled "To Greater Vision" was shown following the lecture.

The membership of the society is now more than 140; approximately 200 persons attended the meeting. —W. A. WILDHACK

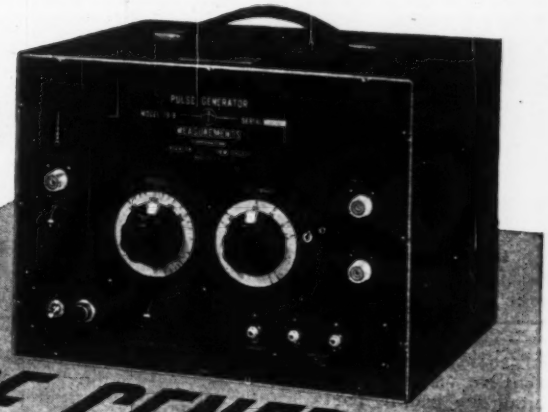
WAYNE COUNTY, MICH.

The regular meeting on Oct. 23 was held at a church hall out in the country. The ladies of the church served a good old-fashioned dinner.

Mr. R. A. Wright of the Metrol Co. gave a talk illustrated by slides on Hays control. His talk was chiefly on combustion and showed the application and advantages of automatic control in a boiler house. The slides ran from comic cartoons (showing the difficulties of the operator in trying to maintain hand control) to chart and data showing the hard facts of improved operation and decreased maintenance with automatic control. After the talk Mr. Wright answered numerous questions.

—JOHN MACPHERSON

Laboratory Standards



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OUTPUT IMPEDANCE: 6Y6G cathode follower with 1000 ohm load.

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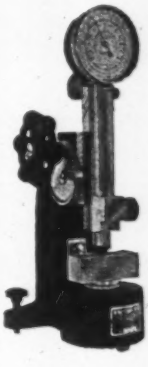

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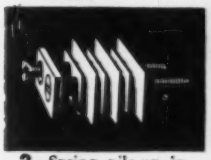

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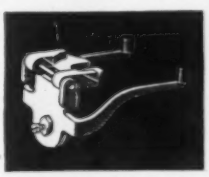

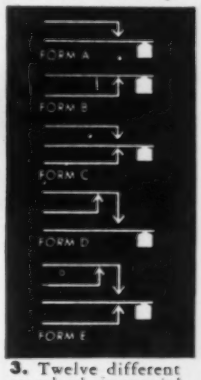

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